Compressed Air Magazine

Vol. 40, No. 3 London - New York - Paris March, 1935

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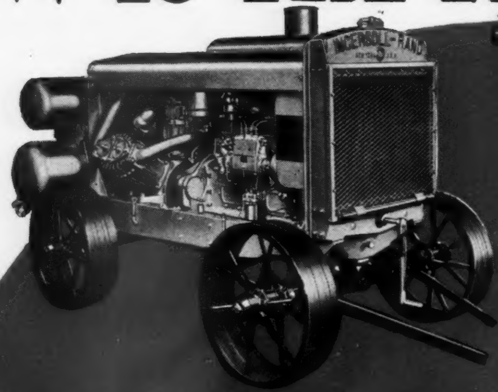

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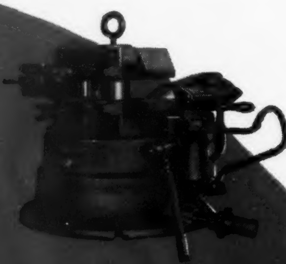

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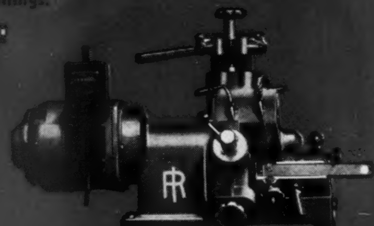

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Compressed Air Magazine

MARCH, 1935

Volume 40 **Number 3**

A Monthly Publication Devoted to the Many Fields of Endeavor in which Compressed Air Serves Useful Purposes

FOUNDED 1896

Business, Editorial and Publication Offices
PHILLIPSBURG, N. J.

Advertising Office
11 Broadway
NEW YORK CITY

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Annual subscription rate: Domestic, $3.00; Foreign, $3.50. Single copies, 35 cents.

Manuscripts intended for editorial consideration should be accompanied by return postage.

Fort Peck Dam

HAROLD O'CONNELL

Part I—The Project and Its Scope

FORT PECK DAM at Fort Peck, Mont., PWA Project No. 30, has challenged the imagination and fancy of engineering and construction circles since its inception. It has been variously hailed as a huge power-production scheme, an immense irrigation plan, and as the second largest dam in the world. In building the dam, however, the Government minimizes irrigation and power development and stresses the benefits to be derived by navigation—the success of the Missouri River Navigation Program depending upon a channel with a minimum depth of 8-9 feet and open nine months of the year from Sioux City, Iowa, to St. Louis, Mo. Without adequate artificial storage of headwaters, this channel cannot be maintained.

From the standpoint of size, Fort Peck Dam is not outstanding when compared with other structures of its kind. Boulder and other dams exceed it in height; the St. Lawrence, the Boulder, and the Muscle Shoals dams, as well as the Bonneville and the Grand Coulee which are now under construction, outclass it in potential power production; and the Assuan and others impound a greater volume of water. And yet Fort Peck is the biggest earth dam that has ever been attempted: judged alone by the amount of fill required to build it, it can claim the title "the world's largest." But size, in itself, would not make the construction of the dam the engineering feat that it is. Difficulties imposed by the nature of the topography immediately surrounding the site, and its remoteness from industrial and power centers, are contributing factors.

New Tunneling Record Set by Fort Peck Dam Builders

DURING two successive months, the best previous records made in advancing the tunnel headings have been exceeded in one of the pilot bores of the Fort Peck Dam diversion tunnels. The lastest mark set was the driving of 1,508 feet in 29½ working days between January 23 and February 23. This bettered the record of 1,358 feet in 31 days established during the preceding month of 31 days.

The four diversion tunnels will be circular in section, 26 feet in diameter and from 5,200 to 7,150 feet long. The pilot tunnels, driven as bottom headings, are of horseshoe section and measure approximately 13x13 feet. The progress recorded above was made in what is known as No. 3 Pilot Tunnel Heading, and the formation penetrated is Bearpaw shale. A detailed description of the tunneling methods employed will be printed in the third article of this series.

Despite its name, Montana, meaning region of mountains, is nearly half plain and rolling country broken up by innumerable gullies and watercourses forming rugged "dry" canyons or coulees. The occasional river worthy of the name flowing the year round through this section usually has its source in the mountains to the west or in Wyoming, the adjoining state to the south. The valleys of these streams are the habitat of the small game and wild fowl that have not been driven from the region in the days gone, as has the buffalo. Among the furtive larger creatures that have not been wiped out by the settlers are the deer and antelope, and considerable numbers of these are to be found there today.

Underlying eastern Montana is a series of Mesozoic and early Tertiary formations. In general, these dip gradually to the east; but as their slope is greater than that of the general land surface, the younger formations are exposed on the east and the older ones on the west side. Fort Peck is situated within an outcrop belt of Bearpaw shale, which constitutes the floor of the Missouri River Valley for 100 miles downstream. Bearpaw shale is a familiar term and substance to the residents of Montana. The name is attributed to the Indians who, before the coming of the white man, had

PANORAMA OF FORT PECK DAM SITE

This picture was taken from the west bank, looking eastward across the Missouri River at the area where work is being concentrated. It shows the trestles used for placing gravel at the upstream and downstream toes of the dam, the gantries engaged in driving sheet piling for the cut-off wall, and, in the background, the abutment through which the diversion tunnels will pass. Near the left-hand edge is a 200-foot steel bridge crossing the river and connecting the east-bank trestles with Wiota, which is the terminus of a 13-mile railroad and is on the main line of the Great Northern.

World's Largest Earth Barrier Being Constructed on the Missouri River in Montana by U. S. Engineers

noticed a butte, near Havre, composed almost entirely of a shale that was not unlike a bear's paw in appearance. They therefore called it Bear Paw Butte; and, logically, that name was later used to describe the material in the butte.

The Bearpaw formation is a nearly uniform deposit of clay shale of marine origin. In its undisturbed state it is well consolidated and capable of supporting upwards of 5 tons per square foot. An inherent characteristic of the material is its tendency to weather or slack when exposed to the atmosphere. The formation is highly impervious—its porosity being only about 18 per cent. From experience encountered in well drilling, the shale appears to extend downward as much as 1,000 feet, and at the eastern abutment (the Missouri flows from south to north at the dam site) it rises to an elevation of approximately 2,350 feet and is thinly covered with oxidized and weathered shale. The existence of this material is vital to the construction of Fort Peck Dam.

The flood plain of the valley below—elevation about 2,050 feet—has an alluvium overburden deposited in a huge V-shaped trough that was cut by the river in the long centuries that have passed since the glacial era. The bottom of this trough lies some 150 feet below the present bed level. This overburden consists chiefly of fine sand interspersed with pockets of clay, which was probably washed down from the shale bluffs. Lens-shaped layers of gravel are also found. The glacial till at the west abutment reaches considerable depths, more than 150 feet, but lessens gradually as it slopes toward the waterway. This brief *resume* of the geologic features of the region will give the reader an idea of the conditions facing the builders of Fort Peck Dam.

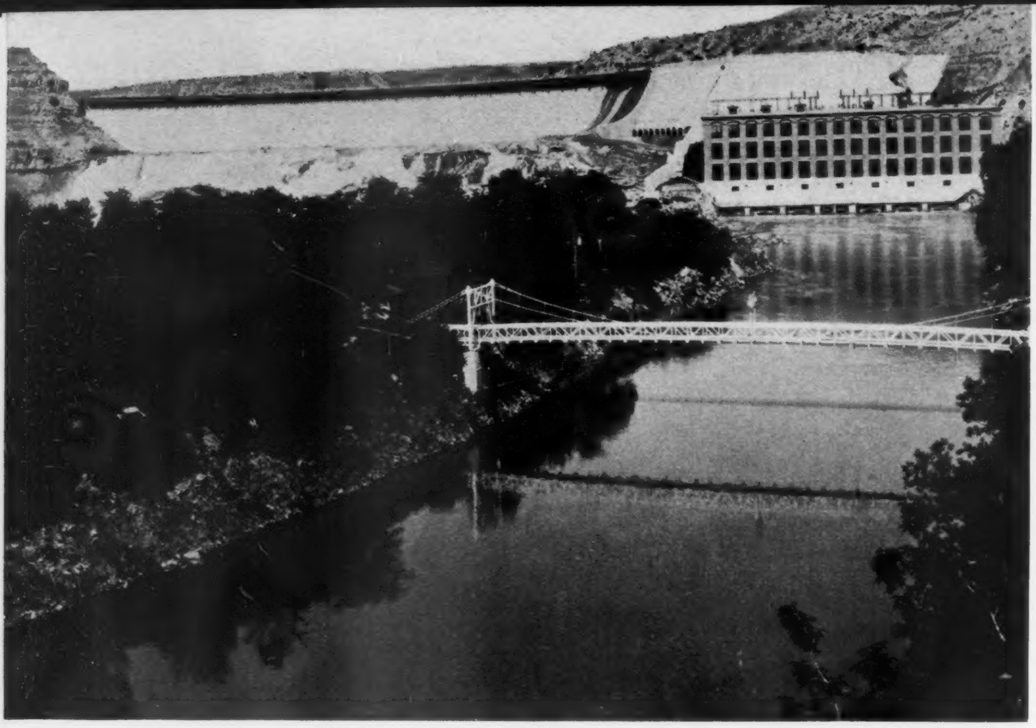
The dam site and its environs have an interesting history. A few miles upstream, on land that has since been swept away by the Missouri, stood old Fort Peck. Established in the days when warring Sioux, Blackfoot, and other Indian tribes made the navigation of a boat or the driving of a caravan a hazardous adventure, that fort was the busy outpost of a trading concern. It was named after Campbell Kennedy Peck because of the prominent part he played in the opening up of the Northwest.

During the Civil War, Peck was one of the first to raise a volunteer regiment in Iowa, subsequently becoming the colonel of that regiment. After the cessation of hostilities, he and Com. E. H. Durfee, of Leavenworth, Kans., entered into a contract with the Government to deliver freight and supplies to military posts and Indian agencies in the Northwest. Under the name of Durfee & Peck, the firm became one of the greatest of its kind in the West. Fourteen small steamboats carried the company flag. On the slow upstream trip they transported Government troops, supplies, horses, and mining machinery: on the speedy return trip the holds were filled with valuable cargoes of furs and Buffalo hides destined for St. Louis. Colonel Peck died in 1879 while returning from Washington where he had been working to arouse interest in Missouri River navigation and in the enlargement of old Fort Peck.

A few miles northeast of the dam site is the Fort Peck Indian Reservation, the former home of the Assiniboin, Brulé, Sante, Teton, Hunkpapa, and Yanktonnais tribes of the Sioux. This reservation is now partly homesteaded. Despite changing times the name Fort Peck has persisted, and it is therefore appropriate that it

STRIPPING OVERBURDEN

From 4 to 25 feet of material was removed from the area between the trestles, where the base of the dam will rest. In the foreground is the camp used by the Mason & Walsh Company prior to the completion of the Town of Fort Peck.



HOW A RIVER DAMS ITSELF

Power for rearing Fort Peck Dam is obtained from hydro-electric plants of the Montana Power Company located near Great Falls farther upstream on the Missouri River. Two of the three stations are shown here. They feed electrical energy to the Rainbow Substation, from which it is transmitted over a 154,000-volt, 3-phase line to Fort Peck.

should be given to the dam now underway there.

A project of the nature of Fort Peck Dam must, of necessity, have various angles favoring its construction. In the case under consideration, the immediate benefits will be improved navigation and flood control. In order to maintain a channel 8-9 feet deep from the mouth of the Missouri above St. Louis, Mo., to Sioux City, Iowa, a minimum flow of 30,000 second-feet at Yankton, S. Dak., is required. Therefore, during the nine months of each year that navigation will be practicable, Yankton, or some other suitable point, will be in continual touch with the control station at Fort Peck. As it is needed, water will be released to augment the normal flow from other sources. Conversely, if that supply is adequate, the water will be conserved. For obvious reasons, however, the flow of the Missouri below the dam will never be entirely stopped. As regards flood control, the dam will affect not only the 1,878-mile course of the Missouri but also, to a lesser extent of course, that stretch of the lower Mississippi which carries its discharge.

The main stem of the Missouri above the Fort Peck dam site has a watershed of some 57,725 square miles. Although this represents but one-tenth of the river's total drainage area, it is a very troublesome portion because it is the catchment basin for the melting snow that accumulates in the surrounding mountains in the wintertime. These waters normally come down during the months of April, May, June, and July, at which time they are augmented by the run-off of the spring rainfall. In normal years they are not a menace. It is only when an exceptionally cold spring in the mountainous region suddenly turns into a hot summer, or when one or more unusually cool summers have caused the snow to pile up, that destructive floods are likely to occur.

In June, 1908, a calculated maximum discharge of 154,000 second-feet passed the point at which Fort Peck Dam is now being built. Considering a mean daily flow of 11,400 second-feet, it is evident that some means of impounding the water is not only desirable but also necessary for the protection of thousands of acres of productive riparian land that is now endangered by inundation and heavy erosion. Ordinarily, the annual erosion is as great as 47 acres per mile of river bank.

Some of the acreage that will be freed from flood uncertainties and, consequently, made available for agricultural purposes, may benefit from subsequent auxiliary developments. A total of 80,000 acres of irrigable land may be reclaimed as a result of the project; and, at some future date, the discharge from four diversion tunnels probably will be utilized for generating considerable blocks of primary and secondary power for low-head pumping and innumerable other services in nearby localities.

In addition to the benefits that will be derived from the dam itself, its building at this time is helping to relieve serious local unemployment and distress. Numerous misfortunes have combined to impose much hardship and suffering on the people living in that section of the country; but the situation has been considerably ameliorated because as many as 7,200 men have been put to work on different parts of the undertaking.

Like many western rivers, the Missouri at the point in question flows in a shallow and relatively narrow bed flanked on either side by a flat, fertile flood plain. Also typical of such rivers is the bottom land which continues for some distance away from the river and ends abruptly at the edge of steep, barren bluffs of Bearpaw shale. Where the dam is to rise, however, the bluffs come comparatively close together, and there the U. S. Army Engineers are now engaged on the initial stages of the construction program that will cost upwards of $86,000,000.

The dam will impound 19,412,000 acre-feet of water in a reservoir that will extend upstream for nearly 180 miles. This 245,000-acre lake will have a shore line of 1,600 miles and a maximum width of sixteen miles. The main structure will have a height of 242 feet above the present river bed, a maximum base width of 2,875 feet, and a crest length of approximately 9,000 feet. The total length of the crest, however, will be 20,500 feet—the west abutment

continuing in the form of a dike 11,500 feet long. As already mentioned, it will be the greatest earth dam of man's making.

To provide the 100,000,000 cubic yards of hydraulic fill that will be needed, four 28-inch, 12,500-hp. electrically operated dredging units will pump water and silt from borrow pits immediately above and below the dam. Each unit consists of a suction dredge, of a booster barge, and of a land booster car with connecting pipe lines. In addition, 4,000,000 cubic yards of gravel and 1,600,000 cubic yards of rock will be placed.

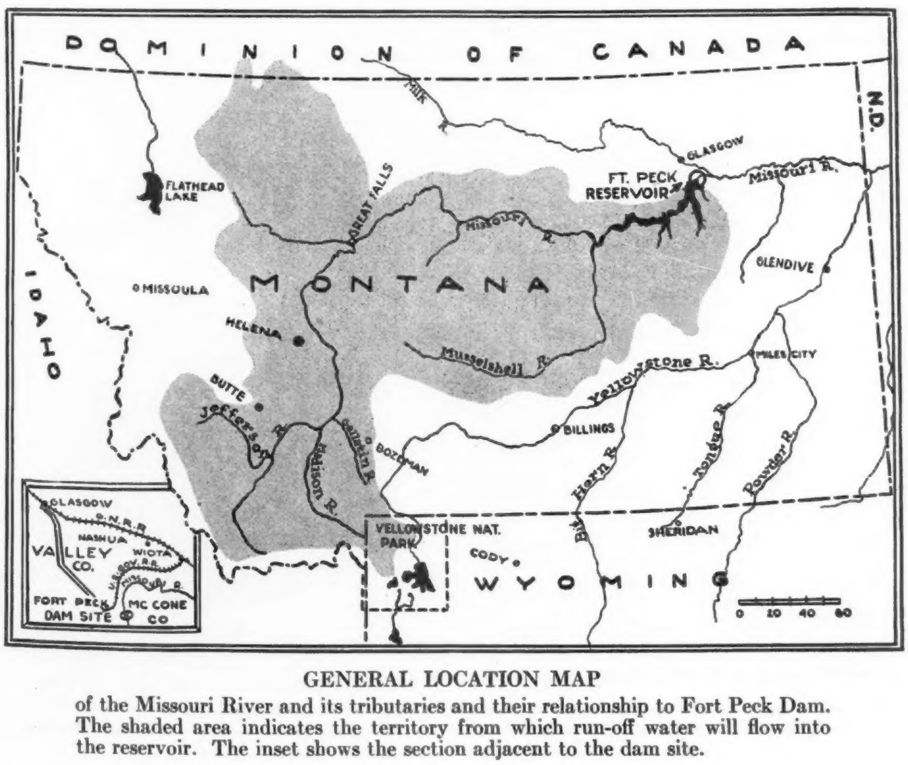
Four diversion tunnels will divert the Missouri River around the dam during and after the filling in of the higher levels. These tunnels are being driven on the east bank where there is a continuous formation of Bearpaw shale that is penetrated readily by the air-driven tools on the job. Their average length is 6,160 feet; and their construction will require about 75,000 tons of steel and 600,000 cubic yards of concrete.

Dependent upon pool height, the tunnels will discharge from 35,000 to 84,000 second-feet. Since this is below the maximum flood on record, a spillway is being built with a capacity of 255,000 second-feet. Independently of the tunnels this will take care of the maximum flood expected at an 8,000-year frequency. The spillway lies east of the dam, and the water discharged from it will reach the river channel at a point 8½ miles downstream. This unusual location is made possible by the long valley of an existing coulee which almost connects with the Missouri swinging to the east immediately below the dam. But despite this, some 13,000,000 cubic yards of material—half overburden and half firm shale—will have to be excavated. The spillway will contain 400,000 cubic yards of concrete in its gate structure, cut-off wall, and lining. The latter will be reinforced and will call for 18,000 tons of steel.

TWO NEW MONTANA TOWNS

An aerial view of Wheeler, about three miles from the dam site. Lakeview is at the upper right. The oiled highway connects Fort Peck with Glasgow. Alongside is the transmission line which carries electrical energy 288 miles from Great Falls to Fort Peck. Some of the region in the background will be inundated by the reservoir that will extend upstream for nearly 180 miles.

The land to be flooded by Fort Peck Reservoir consists largely of public domain: there are no towns, railroads, surfaced highways, bridges, or other improvements within its confines necessitating expensive relocation. Moreover, the stream above the dam is unusually free from sediment. Studies of those waters indicate that the deposition of silt in the reservoir will be at the rate of 225,000 acre-feet in 100 years. Compared with its total capacity of 20,000,000 acre-feet, this is negligible. Twenty miles below the dam site the Milk River, a heavily silt-bearing stream, flows into the Missouri, and just beyond the Montana-North Dakota line the Yellowstone contributes an appreciable load of erosion silt and volcanic ash. By the time the Missouri reaches Kansas City, it normally carries nearly 400,000,000 tons a year. These facts, together with the favorable geographic conditions, were the determining factors in the selection of the dam site.



GENERAL LOCATION MAP

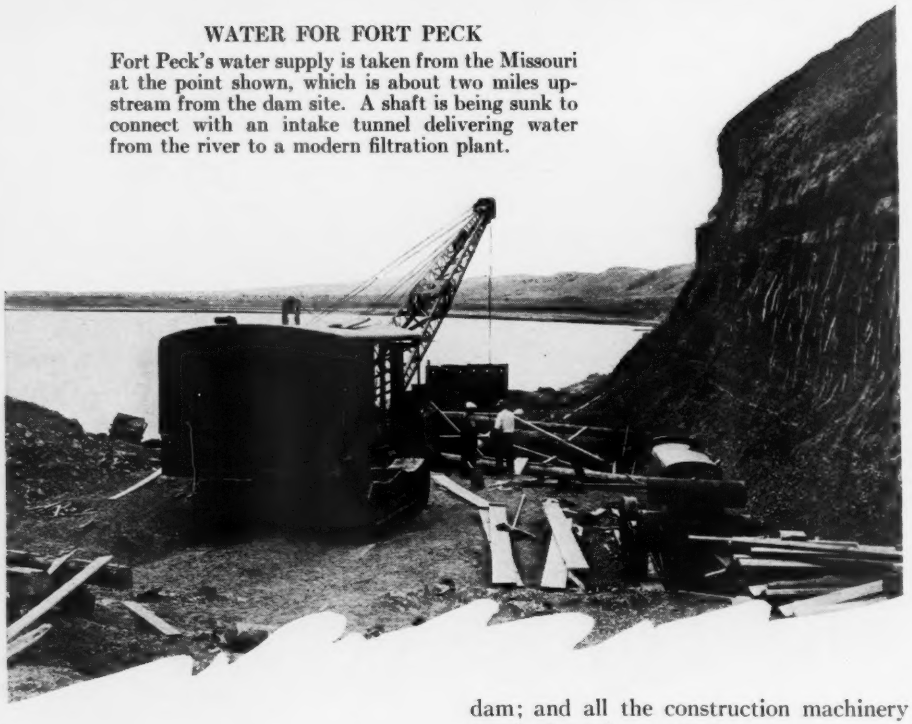
of the Missouri River and its tributaries and their relationship to Fort Peck Dam. The shaded area indicates the territory from which run-off water will flow into the reservoir. The inset shows the section adjacent to the dam site.

Work on Fort Peck Dam began on October 23, 1933, just nine days after it was approved as PWA Project No. 30. On that date a force of 70 men began clearing the land of underbrush and timber, and the Government set aside an area for a boat yard. Orders from the Chief of Engineers, U. S. Army, Washington, D. C., issued October 25, 1933, established the Fort Peck District with headquarters at Glasgow. The needful personnel was rapidly secured—key positions being filled with experienced men from other districts.

One of the first matters to be dealt with was that of communication both by rail and highway. When activities were taken in hand, the only road to the dam site was unimproved, narrow, and virtually impassable in wet weather. No time was lost in removing the snow and in keeping it open to traffic; and, where necessary, gravel was spread and grading was done. In the meanwhile the State of Montana has completed a new highway about twenty miles long from Glasgow to Fort Peck.

WATER FOR FORT PECK

Fort Peck's water supply is taken from the Missouri at the point shown, which is about two miles upstream from the dam site. A shaft is being sunk to connect with an intake tunnel delivering water from the river to a modern filtration plant.



The construction of a railroad to the scene of operations was of major importance if the work was to proceed without delay and without undue expense to the Government. Starting at Wiota, Mont., on the main line of the Great Northern, a 13-mile branch, including sidings and other essential facilities, was undertaken on December 18, 1933, with June 4, 1934, as the scheduled date of completion. A contract for a bridge across the Milk River was let to the Minneapolis Bridge Company, Minneapolis, Minn. This structure consists of three through-girder spans, each 98 feet 10 inches long, supported by timber pile bents and with timber trestle approaches at each end.

As plans for other phases of the project developed, it became apparent that the railroad would have to be ready sooner if work on the Town of Fort Peck and other activities were to be begun in the spring of that year. Despite the intense cold that prevailed during the latter part of December and early in January, followed by an unseasonable thaw, the road was officially opened on April 16; but it was sufficiently completed before that date to permit the movement of many carloads of structural material to the dam site. It is estimated that a total of 10,000,000 tons of material will have to be transported over the line before PWA Project No. 30 is finished—a service that will call for the use of 200,000 cars or 4,000 fifty-car trains. Among the principal items of freight that have been and will be hauled over the rails are: sand, gravel, cement, and steel for the diversion tunnels and the spillway; piling and steel for the bridge that spans the Missouri at Fort Peck; lumber and building supplies for the town; machinery and lumber for the dredging plant; steel sheet piling for the cut-off wall; rock and gravel for the dam; and all the construction machinery required on the contract.

The Missouri River bridge just referred to was necessary right from the start, as there was no adequate means of transportation to the east bank where the diversion tunnels were driven. It is at the downstream side of the dam, and is designed for vehicular and railroad traffic, being a link in the Wiota line. The structure is approximately 13,000 feet long and of the combination truss-and-trestle type—the main channel being spanned by one 200-foot steel truss on concrete piers, by steel trestles on concrete piers, and by steel trestles on timber bents, while the remainder consists of timber and pile trestles. The work was awarded to the Massman Construction Company, Kansas City, Mo., and was begun late in February, 1934. The first trainload of material crossed the bridge on October 1, following.

Much thought was given in the early stages of the undertaking to the problem of supplying power for the operation of the dredges and other construction equipment on the job. It was estimated that a maximum of 62,000 hp. would be needed, a large amount that could, it was decided, be provided most economically by running a transmission line to the Montana Power Company's existing facilities near Great Falls, Mont. The completed line is 288 miles long and carries 154,000-volt, 3-phase, 60-cycle current. Two substations were built, one at each end of the system—the Rainbow Substation by the Allis-Chalmers Manufacturing Company, West Allis, Wis., and the Fort Peck Substation by the Westinghouse Electric & Manufacturing Company, Pittsburgh, Pa. The contract for the line itself was awarded to the Ziebarth & Walker Company, Los Angeles, Calif.

The remoteness of the dam site from a sizable community, the great number of persons to be employed there, and the rigorous climate of the region, combined to demand the development of a town. All but thirteen of its buildings are of a temporary nature; but this does not mean that they are flimsy. Structures must be substantial and tight to assure health and comfort to the occupants because the local yearly temperature normally ranges from 110° above to 40° below zero Fahrenheit. The temporary houses are of wood frame construction and have double-siding outer walls sealed with insulating material, interiors finished with insulating board, and double floors as well as double entrance doors. To prevent the monotony common to most construction camps, the streets have been curved, the architecture has been varied, and the buildings have been painted in pleasing colors that harmonize with the intervening lawns and grounds landscaped with indigenous trees and shrubs.

The laborers are quartered in nine blocks of bunkhouses. There are sixteen of these to a block, each of which is capable of accommodating 384 men. Every block has its own mess hall which seats half that number, and also has two separate bathhouses with eighteen showers in each. Plenty of hot water is always available. There is no overcrowding in the bunkhouses. Only 24 men are assigned to each, contributing greatly to their comfort.

Adjacent to the laborers' quarters are three blocks of foremen's dormitories numbering eight to a block and fifteen rooms to a dormitory. Each of the latter has adequate shower and toilet facilities; and in every block there are a mess hall, with a capacity of 120 men, and two garages for 52 cars. In addition there are nine blocks of houses for the married executives and those engaged in supervisory or administrative work. Twenty-two of the 264 homes in this section are of the duplex type,

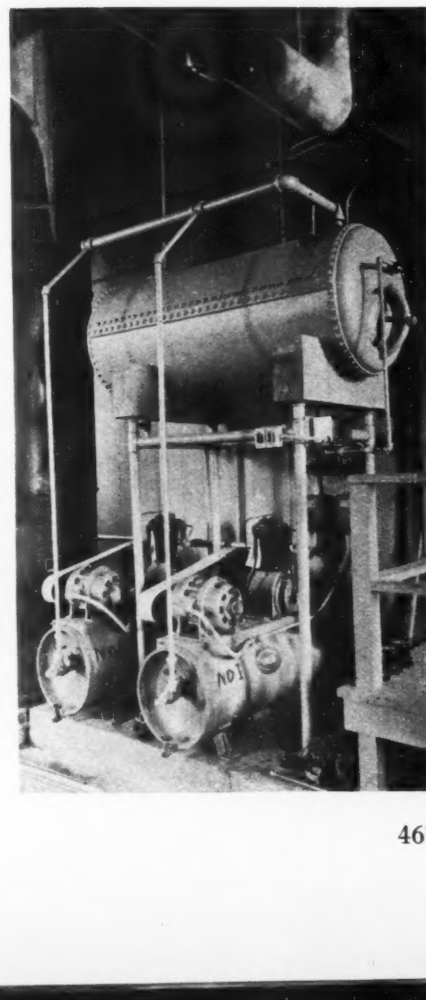
IN COMMAND

Maj. Thomas B. Larkin, U. S. Corps of Engineers, Fort Peck district engineer, who is in direct charge of all construction activities at the dam site with headquarters at Fort Peck.

TOWN OF FORT PECK

The story of the transformation of a tract of barren prairie into a townsite in seven months forms one of the interesting chapters in the account of the Fort Peck project. In that short space of time complete facilities have been provided to serve a population of approximately 3,250 persons. Electric, natural-gas, water-supply, and sewage systems have been built, streets graded and surfaced, and fire and police departments organized. Among the public buildings erected are a garage, stores, a motion-picture theater, a community hall, a hospital, a grade school, a hotel, and a laundry. In the foreground are the quarters of the U. S. Army Engineers in charge of construction. These, and the administration building at the extreme left, will remain after the dam is completed. In the background are the temporary houses for executive, supervisory, and administrative employees and their families. The barracks are not shown.

In addition to performing much work on the dam site itself, compressed air is also put to use in the town. To the right are two air-cooled compressors which are installed in the Fort Peck laundry.

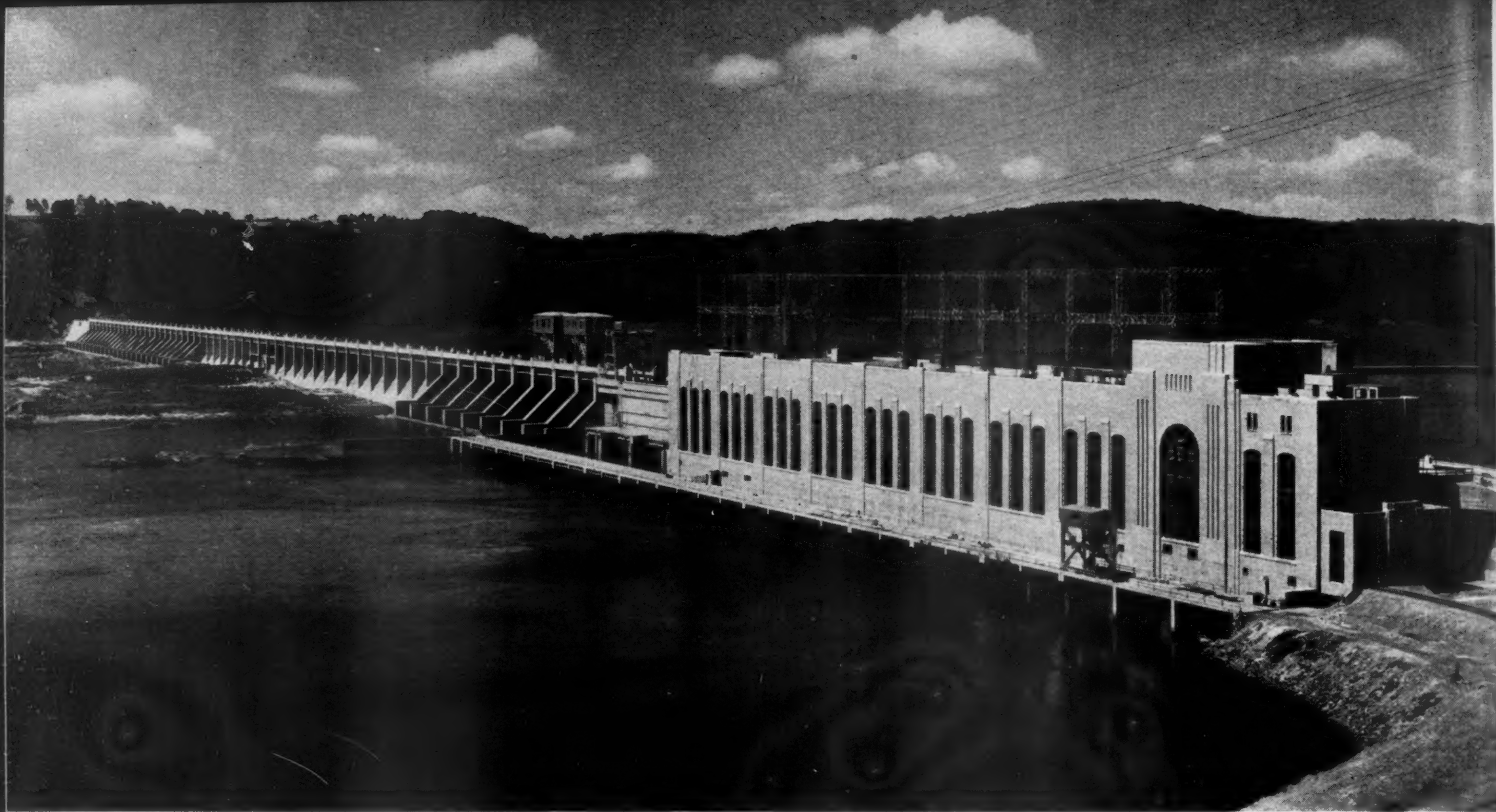


thus providing suitable dwelling places for 286 families of two persons or more.

To guard against the cold winters of Montana, the heating plants must be of generous proportions. All buildings throughout the town and project generally are equipped with furnaces burning natural gas drawn from the Bowdoin field in Phillips County lying to the west. Current for lighting purposes is delivered from Great Falls over the new electric power line. Convenient stores in town handle groceries and foodstuffs for household use, while a modern cold-storage plant and a commissary warehouse supply the contractors' and Government mess halls with provisions.

Water for the community is taken from the Missouri River at a point two miles above the dam site and is pumped to a modern treating plant and reservoir on high ground west of Fort Peck. There it is filtered, aerated, and chlorinated before it is pumped to an underground storage basin. The sewerage system that has been installed collects all the drainage and discharges it into the stream far enough below the town to assure satisfactory disposal. A 22-bed hospital completes the facilities that have been provided for the comfort, safety, and well-being of the people who will live in this more or less isolated place until the great PWA project is completed.

(*To be continued*)



GENERAL VIEW OF SAFE HARBOR DEVELOPMENT

Looking upstream from the eastern shore of the Susquehanna River, with the power house in the foreground. The over-all length of the dam and power house is 5,014 feet. Incorporated in the dam are 32 spillway gates having a combined discharge capacity of 1,150,000 second-feet, or about 60 per cent more than the maximum recorded river flow during flood stage.

Thwarting Ice Pressure With Air Bubbles

R. G. SKERRETT

THE Safe Harbor hydro-electric development, on the Susquehanna River, was described in the June, 1931, issue of this magazine. At that time construction work was underway, and our purpose then was to outline the main features of the project and to deal with the means and methods being employed to carry it forward. Although the first of the concrete was placed on August 1, 1930, still the general contractor made such rapid progress that one of the generating units could be put in service early in December of the next year.

It will be recalled that the dam, with the associate power house, was designed to raise the level of the river so as to assure a head of 55 feet at the turbines—creating an impounding area of more than ten square miles. To achieve this, it was necessary to rear extensive cofferdams that would permit the unwatering of a great area of the river bed, and then to excavate within those enclosures a total of 389,000 cubic yards of rock so as to anchor the dam and the power house and to clear the way for the tailrace. In the latter case, the rock was removed to a depth of 44 feet—difficult work that was made possible by using wagon drills. In these operations, batteries of compressors supplied the large volumes of air needed to actuate rock drills, drill sharpeners, oil furnaces, and other essential apparatus. Now that the Safe Harbor development has been in regular service for several years, it is appropriate to detail the different ways in which compressed air is counted upon to aid in the functioning of the plant and in safeguarding it from seasonal conditions that otherwise might interfere with operations or do more or less damage to parts of the installation.

To appreciate the value of what compressed air continues to do at the plant—the term plant embracing the entire undertaking, one must keep in mind the fact that the dam and the power house form a continuous barrier, from bank to bank of the river, having a total length of 5,014 feet. The power house, alone, is 920 feet long and adjoins the eastern flank of the stream, while the dam proper has a length of 4,094 feet. The dam is equipped with 32 large spillway gates—eight near the power house and 24 in line with the western channel of the Susquehanna. These serve to close the spillways so as to raise the impounded water to the desired maximum height or to permit its escape over the crest of the dam either in equalizing the normal flow of the river or in providing ample channels of release when the stream is in flood. In short, the efficient working of the gates is indispensable at all times; but their integrity and workability become matters of outstanding importance when the river is on one of its recurrent rampages or when wintertime brings the menace of ice.

The watershed of the Susquehanna is a vast one, covering more than 27,000 square miles in the three states of Pennsylvania, New York, and Maryland; and because of the character of the country, something like 51 per cent of the total rainfall is discharged by the river into Chesapeake Bay. Depending upon the weather and the season, the volume of flow at Safe Harbor may range all the way from 2,200 second-feet to as much as 725,000 second-feet. To hold up against the latter tremendous volume sweeping seaward and, at the same time, to permit the excess to pass the dam through the spillway gates, the structures were carefully and generously proportioned to insure an ample margin of stability and strength. Indeed, the spillway gates are so dimensioned that the openings controlled by them will allow the discharge of 1,150,000 second-feet when the pond level attains the contemplated maximum height of 227 feet above the sea. Sudden floods have been caused by extremely heavy rainfalls—some of them cloudbursts, by the rapid melting of snow, and by the surge of pent-up water released by the breaking of an ice jam.

The lower Susquehanna lies in a region where the winter is not infrequently severe and somewhat protracted; and during cold weather ice is formed to considerable

thicknesses on the surface of the stream, and may imperil an arresting structure in a number of ways. For instance, water while freezing is increased 8.4 per cent in volume, and if the ice be confined at that time the expansive force, which is cumulative, may develop tremendous pressure. Should the temperature rise, further expansion is induced and will bring in its train resultant pressures of great magnitude when the ice is not free to spread. Finally, masses of ice when in motion, because of water currents or the impulse of the wind, will exert pressure, the measure of which depends upon the weight of the body of ice and the speed of its advance. Such being the case, the engineer must anticipate these conditions and do what he can to minimize their effects upon the structure exposed to them. The stresses, if not offset, may have behind them pressures of 5,000 or more pounds per linear foot of exposure.

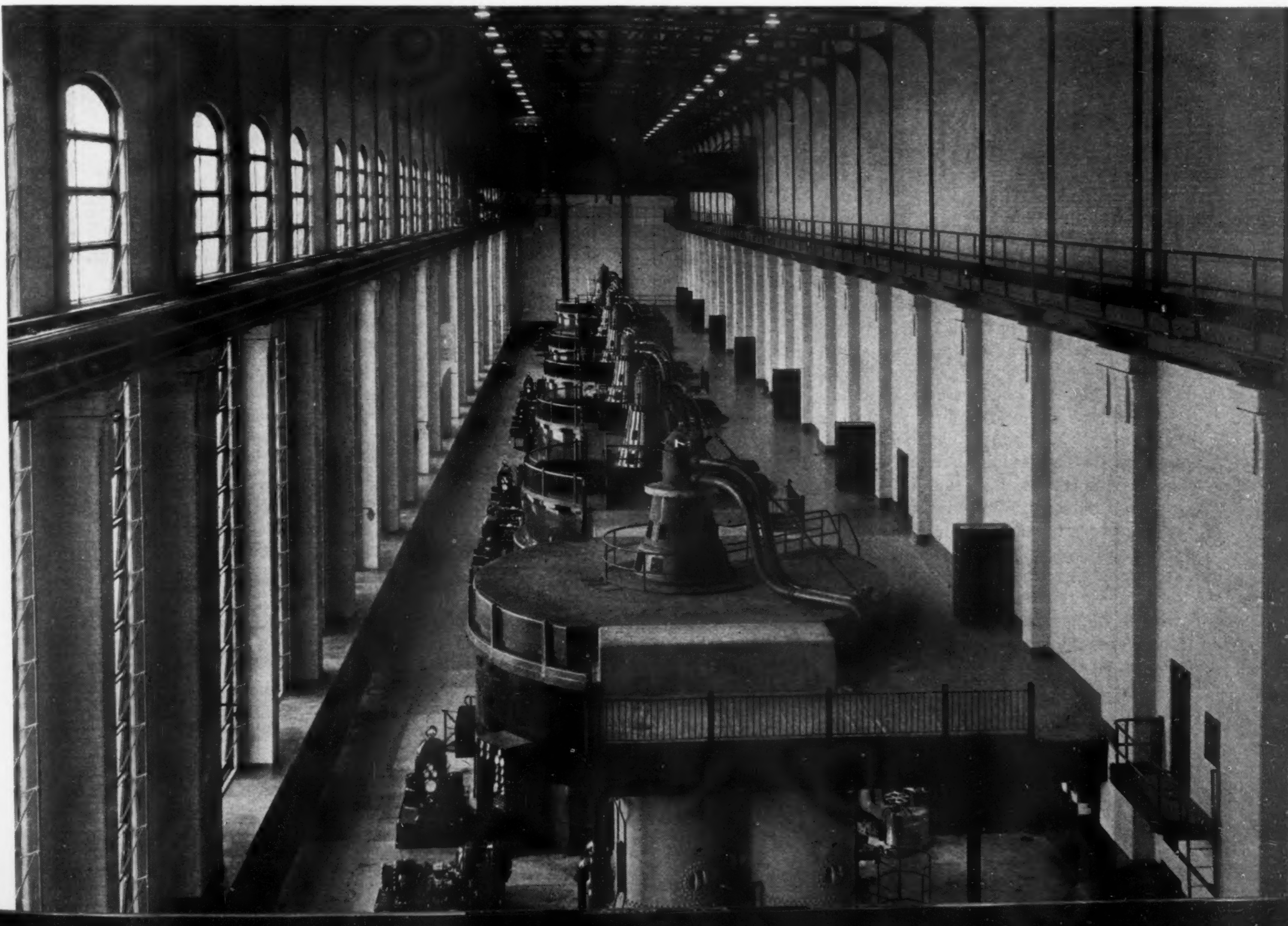
At Safe Harbor the spillway gates are protected from the direct pressure of ice in the pond above the dam by a compressed-air defense, consisting, in its immediate application, of a system of bubblers from which compressed air is discharged into the water at a suitable depth in front of each gate on the upstream side. Free-flowing ice in the open river is kept away from the turbine intakes by a rock jetty and a skimmer wall that form two of the enclosing sides of the forebay: the other two sides are the power house and the east bank of the Susquehanna, which is approximately parallel to the skimmer wall. The latter, which has a length of 1,500 feet, is made up of a series of concrete piers anchored to the rocky river bed, and carries on its outer side a reinforced-concrete curtain that reaches from the upper level of the structure down to 17 feet below the normal surface of the river. Water, therefore, enters the forebay below the bottom edge of the curtain, and floating ice and trash are directed to the eight spillway gates that are grouped near the power house. The water within the forebay is thus combed of floating bodies moving on or close to the surface of the river; but partway water-logged trash may enter the forebay. Such material is kept away from the turbines by sturdy screens placed at the three inlets that admit water to the intake of each of those units.

It should be self-evident that while the forebay constitutes an exclusive area separated from the open river, there is nothing to prevent the water so circumscribed from freezing when the temperature is low enough, and, in freezing, from developing troublesome lateral pressures. But there is a defense against the ice so formed that protects the curtain of the skimmer wall. That curtain is doubly safeguarded: there are compressed-air bubblers on the river side as well as on the forebay side of that concrete barrier. The object of both installations is to keep the ice from bearing against the sections of the skimmer wall suspended between the succeeding supporting piers and, instead, to transfer any ice pressure to the piers which are structurally capable of meeting all likely service conditions. In fact, the skimmer wall was designed to have a factor of safety of two against an ice pressure of 4,000 pounds per linear foot on the outer side and 2,000 pounds per linear foot on the forebay side. The average span between the skimmer-wall piers is 53 feet; and the intermittent sections, which constitute expansion joints, have a horizontal spread of 30 feet. In either case, it is easy to calculate the pressure that may be developed against the unit sections or the entire length of the curtain should ice press upon one or the other side of it.

The 32 spillway passages are each 48 feet wide, and the control of water through them is regulated by the vertical movement of that number of Stoney gates. All but four of the gates are massive panels that are raised or lowered as single bodies by means of mobile cranes. Those four gates, which are for nice regulation of the water level in the pond, are of a double-leaf overlapping type, and the upper and

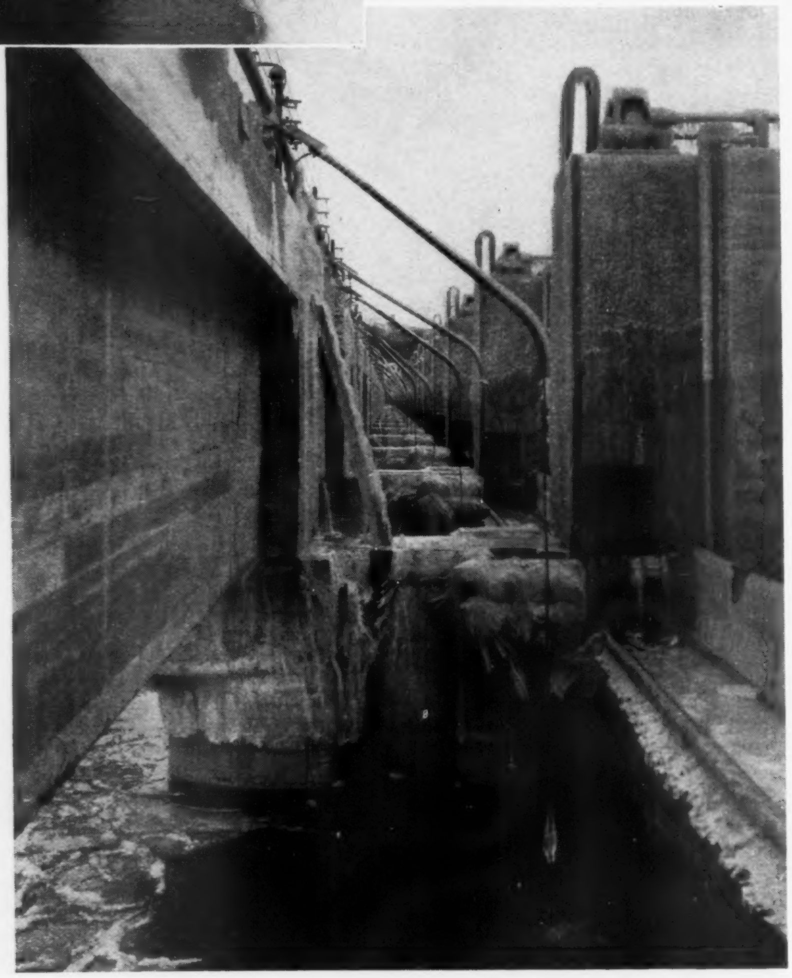
GENERATOR ROOM

Each of the six units shown generates 42,500 hp., making the present capacity of the plant 255,000 hp. or one-half of its ultimate output. Two of these units have been added during the past two years, largely in consequence of the electrification program of the Pennsylvania Railroad. The generators operate under a head of 50 feet.



HOW AIR BUBBLES PROTECT DAM STRUCTURES

Compressed air liberated beneath the water's surface prevents the formation of ice which might cause damage through its expansive force or by clogging gate-operating mechanisms. The upstream side of a part of the spillway section is shown below. Near the bottom of the picture can be seen the area of agitation where bubbles are rising to the surface around the air delivery pipe. These pipes are spaced every 20 feet. The spillway gates are to the right of the air pipes. Ice is allowed to form on the piers which support the gates, as these structures are designed to withstand heavy pressures. To the left is a view along the forebay side of the skimmer wall showing how ice is prevented from forming. The upper pipe of the railing on the near side is a 3-inch air main.



the lower leaf can be moved independently to provide openings differing widely in area. The gate—single or double-leaf—at each opening travels up and down between two massive piers, each of which is slotted and equipped with roller tracks to reduce friction when lifting and lowering those heavy structures. The upper leaf of each of the double-leaf gates is handled by its own electric hoist and not by the cranes that serve the other gates, which are designated as flood gates. To prevent ice from clogging the roller tracks and the sealing contacts between the seatings of the flood gates and the seatings and overlapping points of the double-leaf gates, there are electric heaters that can be switched on and off as occasion requires. These heaters, however, do not protect the gates from the frontal pressure of ice—this indispensable work is performed by compressed-air bubblers. We say indispensable, because strong as these girderlike structures are they might be deformed, if not ruptured, by ice pressure and become jammed and immovable at a time when their opening for the escape of flood waters would be imperative. With this picture of the broad purposes of the skimmer wall and the flood and control gates, now for some details about their pneumatic defenses.

Compressed air for the services mentioned is supplied by the low-pressure system of the station. Because that system is drawn upon for a number of purposes, it is of rather large capacity, being composed of three horizontal, electrically driven, Ingersoll-Rand compound machines. Each unit has a rated capacity of 735 cfm., and the air from all of them is stored at a pressure of 100 pounds in two big receivers, each of which is 17 feet 6 inches high and 8 feet 7 inches in diameter. Air from the receivers is distributed through a 4-inch main that runs the length of the dam. At each gate the main is tapped at two points, 20 feet apart, for $\frac{1}{2}$-inch flexible copper tubes which are passed through $2\frac{1}{2}$-inch extra-heavy supporting pipes—the latter projecting to within 2 feet of the upstream side of the gate. The smaller tubes extend beyond the lower ends of the heavy pipes and down into the water to an approximate depth of 10 feet. By adjustment, the depth can be varied so as to increase or to reduce this submergence to some extent. The $2\frac{1}{2}$-inch pipes are mounted independently on a swivel pedestal that permits a bubbler to be swung to the right or to the left to change its position horizontally whenever more effective performance can be obtained thereby.

The quantity of air escaping from a bubbler is controlled by a small bronze disk, pierced by a hole $\frac{1}{16}$ inch in diameter, that is inserted in the tube at the point of union with the air main. This assures an economical use of air through the regulation of the discharge to meet the prevailing ice condition. The agitation of the water by the ascending bubbles of air, as well as the warmth of the air, suffice to prevent the water so acted upon from freezing directly in front of a gate. The two bubblers at each gate will maintain an area of clear water having a width of 40 feet. As a consequence, any ice pressure is transferred to the spillway piers which carry the gates; and those piers are strong enough to withstand that load. Furthermore, the ice is thus tied to the dam and kept from moving and developing a momentum that might attain damaging if not destructive proportions.

In the case of the skimmer-wall installation, the air main is 3 inches in diameter and forms the railing along the walkway at the forebay side of that barrier. The bubbler tubes are of $\frac{1}{2}$-inch flexible copper, such as are provided at the spillway gates, but they are 10 feet apart. Because of their closer spacing, the orifice in each control disk is only $\frac{1}{32}$ inch in diameter, which admits of a sufficient discharge of air to keep the zone protected by each bubbler free of ice. One of our illustrations shows in a striking way how the bubblers prevent the formation of ice on the forebay side of the skimmer wall. A kindred arrangement of bubblers on the river side of the skimmer wall performs a like service. Any ice pressure on that side of the curtain is, as in the case of the spillway gates, directed to the skimmer-wall piers.

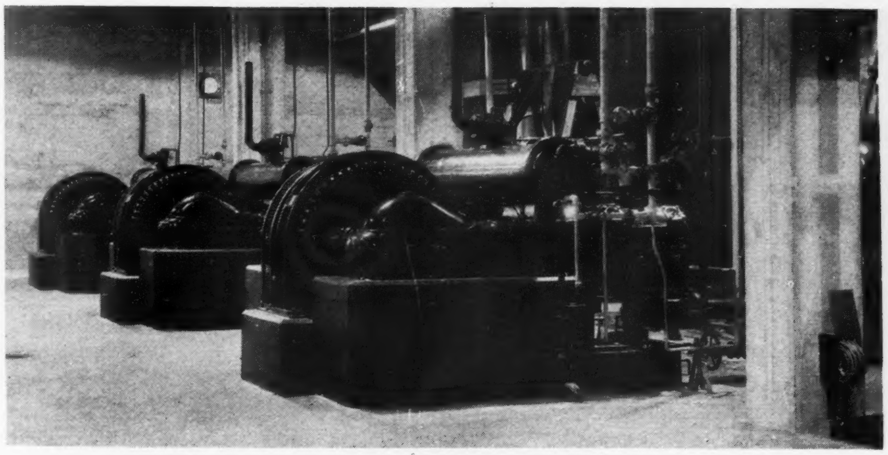
While the turbine intakes have been set deep enough in the water to escape trouble from floating ice, still the inlet screens may become clogged with trash that is either water-logged or nearly so and likely to be drawn to the inlets by the flow of water

from the forebay to the turbines. Each hydro-electric unit obtains its water from the forebay through three openings leading to the intake, and each opening is equipped with four screens. At the bottoms of these screens there are outlets for compressed air; and the air, in mounting surfaceward, is counted upon to carry away any accumulated trash through the action of the induced vertical currents—thus clearing the screens so that a full volume of water can be admitted to the intake of the given turbine.

The importance of this service can best be realized when it becomes known that the plant was first equipped with four main units. In 1933, a fifth unit was installed, and during the year gone a sixth one was put in. The ultimate capacity of the power house, which is 920 feet long, will be twelve main units, each of 42,500 hp. Today when all the hydro-electric generators are in operation, the output is 255,000 hp. The capacity of the Safe Harbor plant has been increased to its present volume largely because of the current requirements of the Pennsylvania Railroad for some of its electrified divisions.

In addition to supplying air for the purposes already enumerated, the low-pressure system at Safe Harbor is the source of motive energy for pneumatic tools; and outlets for that service are provided throughout the station as well as on the dam. It is not necessary for us to enter into details, because all persons familiar with hydro-electric plants know that upkeep and repair call for varied uses of compressed air or air-driven apparatus of one sort or another. One of its unfamiliar applications at Safe Harbor is that in connection with the occasional operating of a main generating unit as a synchronous condenser. Without dealing with electrical technicalities, let us say that by running a motor light it is feasible to improve, for the time being, the power factor or to control the voltage on some part of a power system. In a sense, a unit, at such a time, may be virtually floating on the line. The need of this is, of course, intermittent.

Normally, the runner of any of the big hydro-electric units at Safe Harbor is submerged because the water level of the tailrace is higher than the top of the runner. To operate one of these machines economically as a synchronous condenser, the water in the draft tube, which lies below the runner, has to be depressed to a level lower than the turbine runner. This is accomplished by admitting compressed air above the water and thus forcing it down to the desired point. The result is substantially identical to that obtained in the case of a diving bell, in which the pressure exerted by the air holds the enveloping water at a given level near the bottom of the chamber. Approximately 5,600 cubic feet of air is required within a short interval to effect the unwatering of the runner. In that condition, the runner does not have to churn water but rotates, instead, in the far less resistant air, making it possible to save about 10,000 kw. while it is performing as a synchronous condenser.



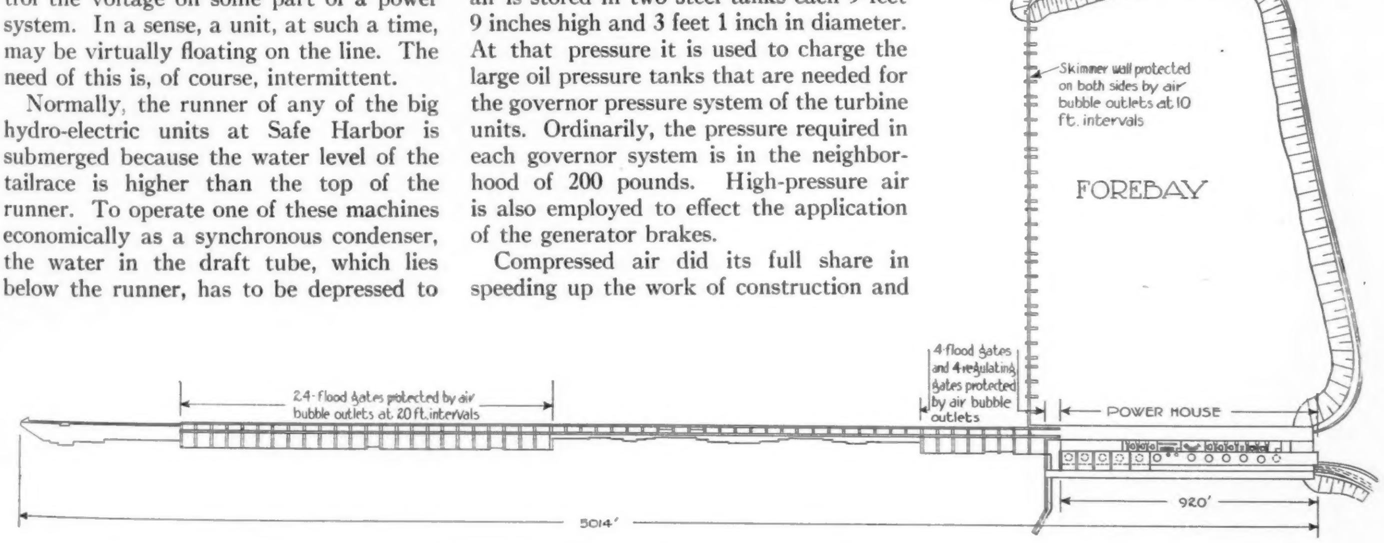
LOW-PRESSURE COMPRESSORS

Each of these synchronous-motor-driven machines delivers 735 cfm. of 100-pound air which serves various purposes aside from that of preventing ice formation. They are termed low-pressure units because there is also a 225-pound-pressure air system which is used to charge oil tanks for the governor pressure system of the turbines.

The Safe Harbor station also has a high-pressure-compressor plant that furnishes air to the high-pressure system. This plant is a comparatively small one, consisting of two, 2-stage, tandem units. Each machine has a capacity of 80 cfm. at a normal pressure of 225 pounds per square inch. The air is stored in two steel tanks each 9 feet 9 inches high and 3 feet 1 inch in diameter. At that pressure it is used to charge the large oil pressure tanks that are needed for the governor pressure system of the turbine units. Ordinarily, the pressure required in each governor system is in the neighborhood of 200 pounds. High-pressure air is also employed to effect the application of the generator brakes.

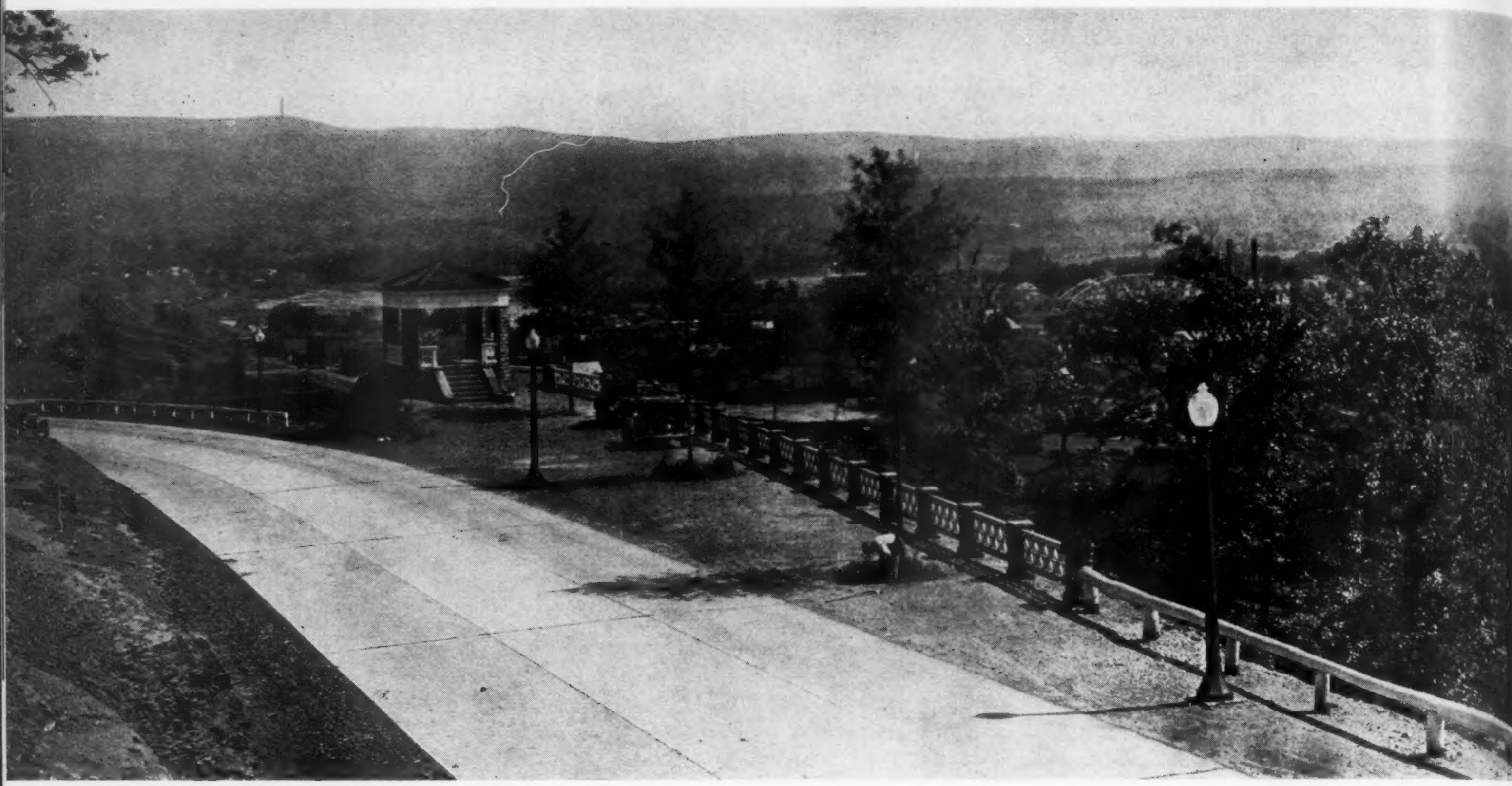
Compressed air did its full share in speeding up the work of construction and in helping to do that work at a reasonable cost; and compressed air, as we have made it clear, is now carrying on in a multiplicity of ways that make the Safe Harbor hydro-electric plant the fine example that it is in all its different departments. With compressed air available, it is more than likely that the men immediately on the job and others having supervisory responsibilities will find still other uses for this adaptable motive agency at the station.

The Safe Harbor development is owned and operated by the Safe Harbor Water Power Corporation; and for much of the information contained in this article we are indebted to N. B. Higgins, chief engineer of that organization. The dam and power house were constructed by The Arundel Corporation of Baltimore, Md.



GENERAL LAYOUT OF SYSTEM

The water which operates the turbines enters the forebay by passing underneath the skimmer wall, a structure which is designed to prevent the entrance of ice and floating objects. Both sides of this wall are protected against the formation of menacing ice by compressed-air jets. Similar installations are provided on the reservoir side of the 32 spillway gates.



SECTION OF COMPLETED PARKWAY
This improved northern entrance to Port Jervis, N. Y., provides a 30-foot concrete roadway flanked by lighting standards and having a 5-foot shoulder on each side. The observation station at the left affords a view of the city below.

Building a Parkway with Relief Labor

FRANCIS X. CONRAD*

A New York City Gains a Useful Structure and Aids 300 Jobless

IN THE winter of 1933-34, Port Jervis, N. Y., found itself with 300 men out of work or on relief rolls, money available for public works, but no undertaking on which such a large number of men could be used. Some project which would give adequate and useful employment to this group had to be started without delay. The city officials asked the engineering department to provide such a project, stipulating that it must be sufficiently practical and necessary to appeal to the taxpayers. Nothing that would meet these requirements could be found among the existing plans, so the department was forced to go afield for ideas.

Mayor Wendell E. Phillips had often expressed a desire to improve the northern entrance to the city via Grand View Avenue, that thoroughfare no longer being equal to the demands of the steadily increasing traffic. Widening and surfacing of the artery were suggested. It needed only a little study to disclose that, while the traffic situation could thus be alleviated, the undertaking would not provide enough work for all the city's unemployed. Then it was that a proposition was made that at first appeared fantastic—namely, to construct an entirely new highway along the side of a mountain which lies to the north of Grand View Avenue and whose slope terminates at that street. Accompanying illustrations reveal why the proposal was at first deemed fantastic. The slope of the mountain is at no place less than 10 per cent, and it ranges up to nearly vertical. Furthermore, the mountain is mostly rock, and it was agreed that no heavy machinery should be employed on the job. Incidentally, while the problem of rock excavation at first appeared to present an insurmountable difficulty, it turned out to be the most satisfactory feature of the project in that, with the aid of compressors, rock drills, and dynamite, it developed into the finest sort of winter-relief work.

*City Engineer, Port Jervis.

TABLE OF UNIT PRICE ESTIMATES

Item	Quantity	Unit Cost	Total Cost
Clearing and grubbing	As necessary		$500.00
Excavating earth	7,500 cu. yds.	$1.25	9,375.00
Excavating rock	35,000 cu. yds.	2.25	78,750.00
Fine grading	8,833 sq. yds.	0.10	833.30
Concrete	8,833 sq. yds.	3.50	30,915.50
Manholes	6	75.00	450.00
Catch basins	12	50.00	600.00
Tile pipe, 18-inch	2,500 lin. ft.	2.50	6,250.00
Tile pipe, 12-inch	150 lin. ft.	1.50	225.00
			$127,898.80
Contingencies and engineering			12,789.88
TOTAL			$140,688.68

Upon receiving word to proceed with the project, the city engineering department began a survey. A preliminary center line was established in the field and all physical topography taken for a distance of several hundred feet to either side of it. The whole mountainside was cross-sectioned, and all survey notes plotted. From these plottings a paper location was made, the center line of which was again established in the field and cross-sectioned. From these data grades were determined and earthwork sheets prepared.

The alignment worked out satisfactorily, but some severe grades were required, particularly at the eastern end. Even with a 9.5 per cent grade a 40-foot cut was necessary at one place. As had been expected, fills would not take all the material excavated from cuts, but it turned out that the surplus could be used elsewhere to good advantage. A width of 40 feet at subgrade elevation was determined upon as adequate. This provided a 30-foot centrally disposed roadway, with 5 feet at each side for shoulders, light standards, etc. Slopes in rock cuts were set at 4 to 1 and in earth cuts at 1½ to 1. Fill slopes were uniformly set at 1½ to 1.

After a thorough consideration of just how the work was to be done, unit price estimates were prepared, as shown in the table on the preceding page. Actual work began two weeks after the project had been definitely approved. During the interval, the engineers had made all preliminary studies, decided on alignment and grade, and staked the area for construction. Approximately 200 men were on hand the first day. They were divided into three groups and assigned to sections at the two ends and in the middle. Their initial task was clearing the right of way.

Wherever conditions permitted it, the line at which the proposed gradient cut the slope was marked with stakes and the men were set to work there prior to grading. With picks and shovels they cut into the hillside and deposited the excavated material on the lower side to make fill. At many points, however, the excavation was wholly in cut, or consisted entirely of rock, so that no handwork could be done until drilling and blasting had taken place.

It will be noted that more than 82 per cent of the excavating was in rock, and it was therefore necessary to employ drilling equipment. An effort was made in the beginning to drill by hand, with the idea of using as much labor as possible, but this plan was soon abandoned because not enough rock could be blasted. Accordingly, while all the work that could be done by hand was underway, the city investigated the equipment field and then purchased four 220-cfm. Ingersoll-Rand portable compressors, eight "Jackhamers," and the necessary accessories. The greatest trouble experienced with this machinery was getting it on the job. Because of the rough terrain over which they had to be moved, the compressors were subjected to considerable rough treatment. They withstood this successfully, however, and, once on the job, operated well-nigh continuously without a single failure being recorded.

LOADING ROCK BY HAND

More than 80 per cent of the excavating was in rock, with cuts up to 40 feet deep. All broken material was loaded by hand with 200 to 300 relief workers grouped from ten to twelve to a truck.

All drill runners were inexperienced at the start, but it was found that with competent supervision they could turn out a satisfactory amount and grade of work. Each compressor was in charge of a mechanic, and supplied air for two drills. Blast holes ranged up to 12 feet deep. Cuts greater than 12 feet were excavated by benching, thereby facilitating loading.

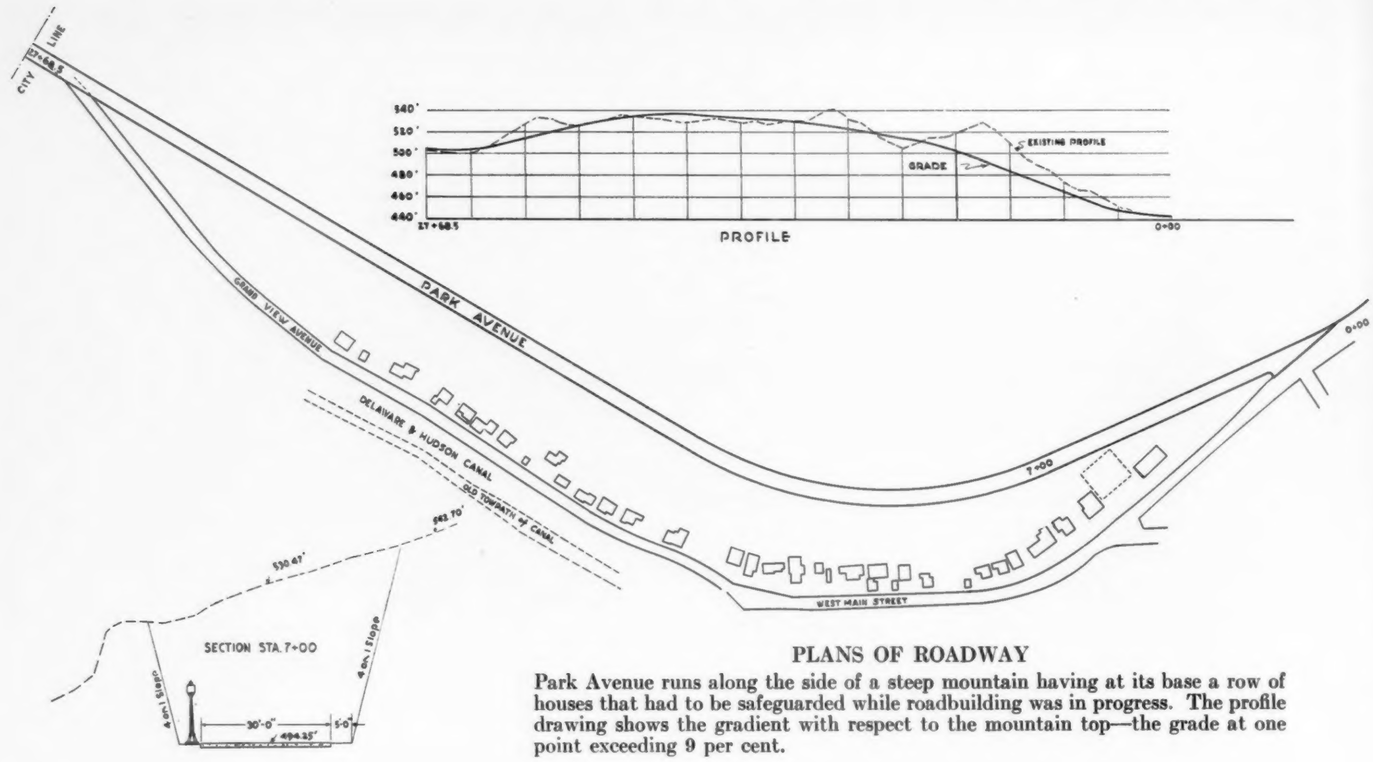
Blasting presented a serious problem. Not only were heavy powder charges required but the roadway was extremely close to houses fronting on Grand View Avenue. As a precautionary measure, explosives manufacturers were asked to provide skilled men to lay out a plan of drilling and shooting that would safeguard lives and property. Blasting mats, originally of hemp and later of steel, were used to cover all blasts where rock was liable to scatter extensively.

Because of the haphazard method of spacing holes, rock was at first broken into all sizes and shapes, some of the pieces weighing a ton or more. As loading was done entirely by hand, this was very undesirable. To correct it, a system of placing holes was developed, and this, together with the employment of suitable amounts of dynamite, resulted in reducing the rock to sizes that could be conveniently handled.

A good deal of the actual grading was done by hand. Such material as was needed for fills came from cuts, and the excess was hauled away in trucks. All trucks were rented on a per hour basis. As there were

BENCHING A HEAVY CUT

"Jackhamer" holes reached a depth of 12 feet. Where deeper cuts had to be made the rock was removed in benches.



PLANS OF ROADWAY

Park Avenue runs along the side of a steep mountain having at its base a row of houses that had to be safeguarded while roadbuilding was in progress. The profile drawing shows the gradient with respect to the mountain top—the grade at one point exceeding 9 per cent.

from 200 to 300 men at work all the time, with ten to twelve loaders assigned to a truck, from 20 to 30 trucks were kept busy.

In building up fills, the dumped material was spread by hand and rolled with a 10-ton gasoline roller. As the major part of the subgrade was in rock cut, it was necessary to provide a cushion between the rock base and the concrete pavement. This was done by excavating 6 inches below the theoretical subgrade and filling to that depth with a good grade of shale and loam soil, which was then rolled. This formed a good base and made it easy to pin the concreting forms into position.

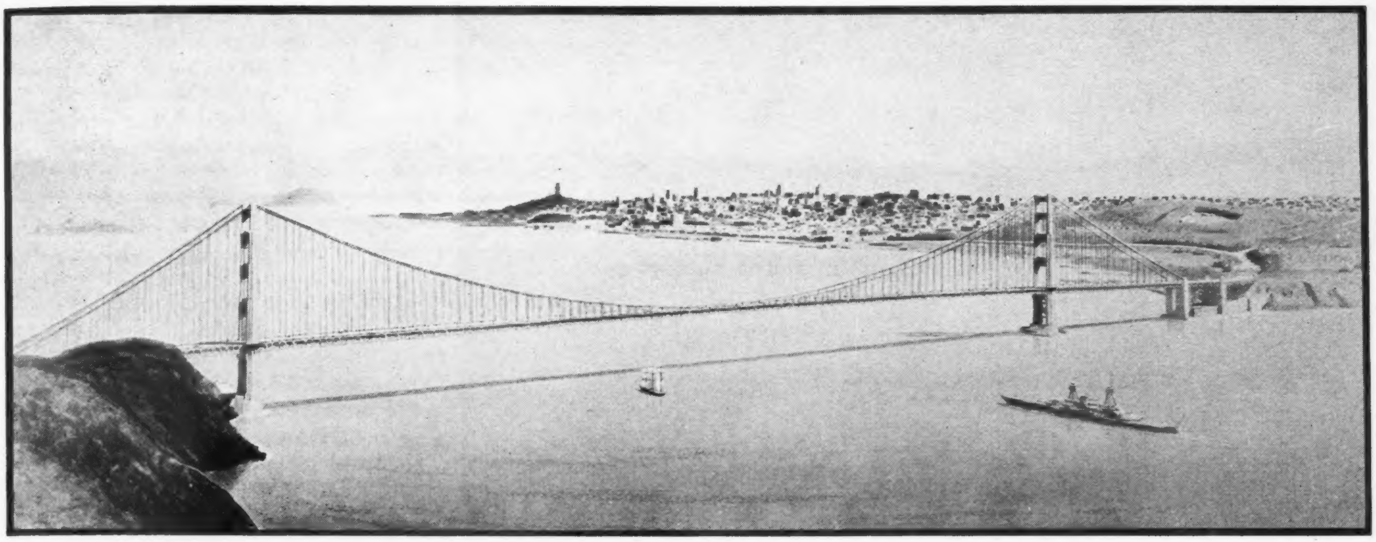
As soon as the subgrade was finished, the city rented a 6-bag paver, a mechanical finisher, and such other equipment as was required for laying the reinforced pavement. The concrete was poured in three panels, each 10 feet wide and 8 inches thick. Expansion joints were provided at 50-foot intervals, using joint material of the premolded type that extended to subgrade and was punched for six dowels. The dowels were of 3/4 inch diameter, with sleeves fitted at one side of the joint to allow for movement.

The total cost of the project was approximately $130,000. This is more than it would have been had the highway been built by private interests. But, as previously set forth, the primary object was to create work that would lend itself to the employment of relief labor. In quality and workmanship the road compares favorably with similar jobs done under contract.

The completed parkway, which has been given the name of Park Avenue, stands as a permanent example of what can be accomplished with relief workers when properly directed, when good equipment is used, and when adequate planning and engineering are assured. The City of Port Jervis feels that it has directly refuted the charge which is sometimes made that relief labor is valueless to a municipality.

DRILLING AND BLASTING

Four portable compressors and eight "Jackhamers" constituted the drilling equipment, hand drilling having been found to be unsatisfactory. Because of the proximity of houses below the line of construction, mats (left) were employed to prevent blasted rock from flying.



AS IT WILL LOOK

Two great bridges—one crossing the bay to Oakland and the other spanning the Golden Gate—are being constructed to end the isolation which natural forces imposed upon the rocky point where San Francisco perches. Upon its completion in 1937, the Golden Gate structure will become the new colossus of the bridge world. Its theoretical traffic-carrying capacity will be 283,000 vehicles every 24 hours. It is estimated that the production, transportation, and erection of the materials entering into it, together with the necessary field operations, will provide 25,000,000 man-hours of work.

Bridging the Golden Gate

LAWRENCE A. LUTHER

**"Thou drawest all things, small or great,
To thee, beside the western gate."**

THESE lines by Bret Harte might well have been inspired by the Golden Gate Bridge which is now gradually taking form at the mouth of San Francisco Bay. That giant span, however, was not conceived when they were written—in fact, probably would have been considered an engineering feat impossible of accomplishment. Be that as it may, the last natural barrier in a direct highway route between San Francisco and the coastal region to the north is being crossed by a suspension bridge that in proportions will have no rival anywhere. Moreover, it is said to be the only structure of its kind ever to be built across the outermost entrance of a leading seaport—in other words, in an exposed position that adds considerably to the difficulties of construction.

Geologists agree that the narrows—better known as the Golden Gate—were formed in the centuries gone by the erosive action of a great river that had its source in an inland fresh-water lake and emptied into the Pacific Ocean. It is this neck of the large bottle represented by San Francisco Bay that is being spanned; and there flood tides pour in at a rate exceeding five miles an hour and surge out again with the ebb as rapidly as seven miles an hour. In spite of the fact that the main span will be 4,200 feet long—full 700 feet longer than that of any other bridge, the pier on the San Francisco side must be placed 1,125 feet offshore and in water having a maximum depth of 100 feet. But let us not get ahead of our story.

In 1917, the City Engineer of San Francisco, the late M. M. O'Shaughnessy, father of the Hetch Hetchy water-supply system, was in communication with three distinguished bridge builders concerning the feasibility of spanning the Golden Gate, and from that period dates the active participation of Joseph B. Strauss, the chief engineer of the undertaking. Choice of a route that lands both ends of the structure on Federal property, among other considerations, necessitated that application be made to the War Department for permission to construct the bridge and its approaches. This was obtained in 1924, and carried various stipulations concerning its normal and emergency use by the Government.

In 1928, an affiliation of six counties as the Golden Gate Bridge and Highway District was effected for the purpose of financing the enterprise; and, by referendum in the November elections of 1930, the citizens of those counties voted to issue bonds amounting to $35,000,000. An exhaustive study of the potential automobile and commutation traffic made previously indicated that it was sufficient to justify the investment. Compared with the service given by the ferries now in operation, it is estimated that the bridge will save 53 minutes per round trip.

The total length of the crossing, including the approaches and shore structures, will be seven miles. The main span will be 4,200 feet long, as already mentioned; each of the two side spans will be 1,125 feet long; and, in addition, there are appurtenant spans which will give the bridge a total length of 8,943 feet between its north and south plazas. The deck, consisting of a 60-foot, 6-lane roadway and two 10½-foot sidewalks, is to have an over-all width of 90 feet. The length of the main span and the 220-foot minimum vertical clearance it assures midway, account for the unprecedented height of the towers, 746 feet above mean high water. In this respect they will surpass any structure in the bay cities; and the roadway will be at a level equivalent to that of the roof of a 25-story building.

The San Francisco approach to the bridge includes three viaducts—two of steel, 1,078 and 1,650 feet long, respectively, and a 2,911-foot concrete structure. It crosses the Presidio, which is perhaps our most picturesque military post. There is located Fort Point, over which the bridge will pass on a 319-foot steel arch. Fort Point is long since obsolete, but was considered the last word in harbor defense when it was completed in 1861. Inasmuch as the bridge will join two large military stations, it may be of interest to recall that another fortress, Castillo de San Joaquin, preceded Fort Point. Built in 1794, with 10-foot thick adobe walls and tule-thatched roof, it was garrisoned by a cor-

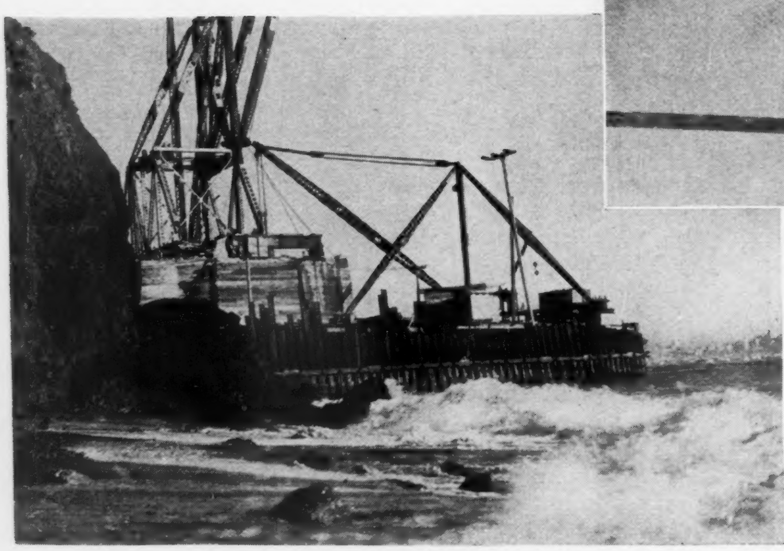
WHERE THE BRIDGE WILL CROSS

In the foreground (above) is the concrete fender which was built at the site of the San Francisco tower to protect its pier against the prevailing strong tides and shipping. Through a change in plans it was also utilized as a cofferdam within which the pier was constructed 1,125 feet offshore. The virtually completed Marin tower is seen on the opposite shore.

poral and six artillerymen and mounted eight Spanish 12-pounders.

Preliminary work on the great project was undertaken on November 28, 1932, but actual construction was not officially begun until January 5, 1933. The contract for the two cable anchorages and piers supporting the approach spans was awarded on a bid of $1,859,854 to Barrett & Hilp of San Francisco. Both cable anchorages have their footings in rock, and the eyebars to which the cables will be attached are embedded in twin blocks of concrete. Each of the two suspension cables will be 7,649½ feet long and 36½ inches in diameter, and will exert a pull of 63,000,000 pounds on each of its anchors, while each of the blocks in an anchorage will have a resistance of 126,000,000 pounds.

The material underlying the south or San Francisco anchorage is a serpentine of low tensile strength which necessitated giving it sufficient mass to overcome the pull to which it will be subjected. Each of its two blocks is 135 feet high, 60 feet wide, and 165 feet long—the finished structure containing 68,320 cubic yards of concrete. They were poured as a series of interlocking reinforced blocks with the eyebars embedded in tiers. A total of 127,000 cubic yards of material was excavated in placing this anchorage; and Insley chuting towers delivering through "elephant trunks" were employed in pouring it as well as the smaller



THE SEA'S AUSTERITY

These two views, one at either shore, convey an idea of the relentless force with which the tides at the Golden Gate resisted man's efforts to invade their precincts. At the left is the pier for the Marin tower in place, with the steelworkers' derricks erected. The site of the San Francisco tower pier is shown above.

north shore or Marin anchorage, which required but 58,970 cubic yards of concrete. Work on both went forward without delay, and was largely completed in 1933.

To supply the 200,000 cubic yards of concrete for the San Francisco anchorage, main and auxiliary piers, and other parts of the substructure, a storage and batching plant was set up on a wharf about half a mile from the construction site by the Pacific Bridge Company of Portland, Ore., while a similar plant with less capacity was provided by Barrett & Hilp on the Marin County side to serve the pier and anchorage there. A moderate amount of dredging had to be done to permit the delivery of cement and aggregates to these points by barges.

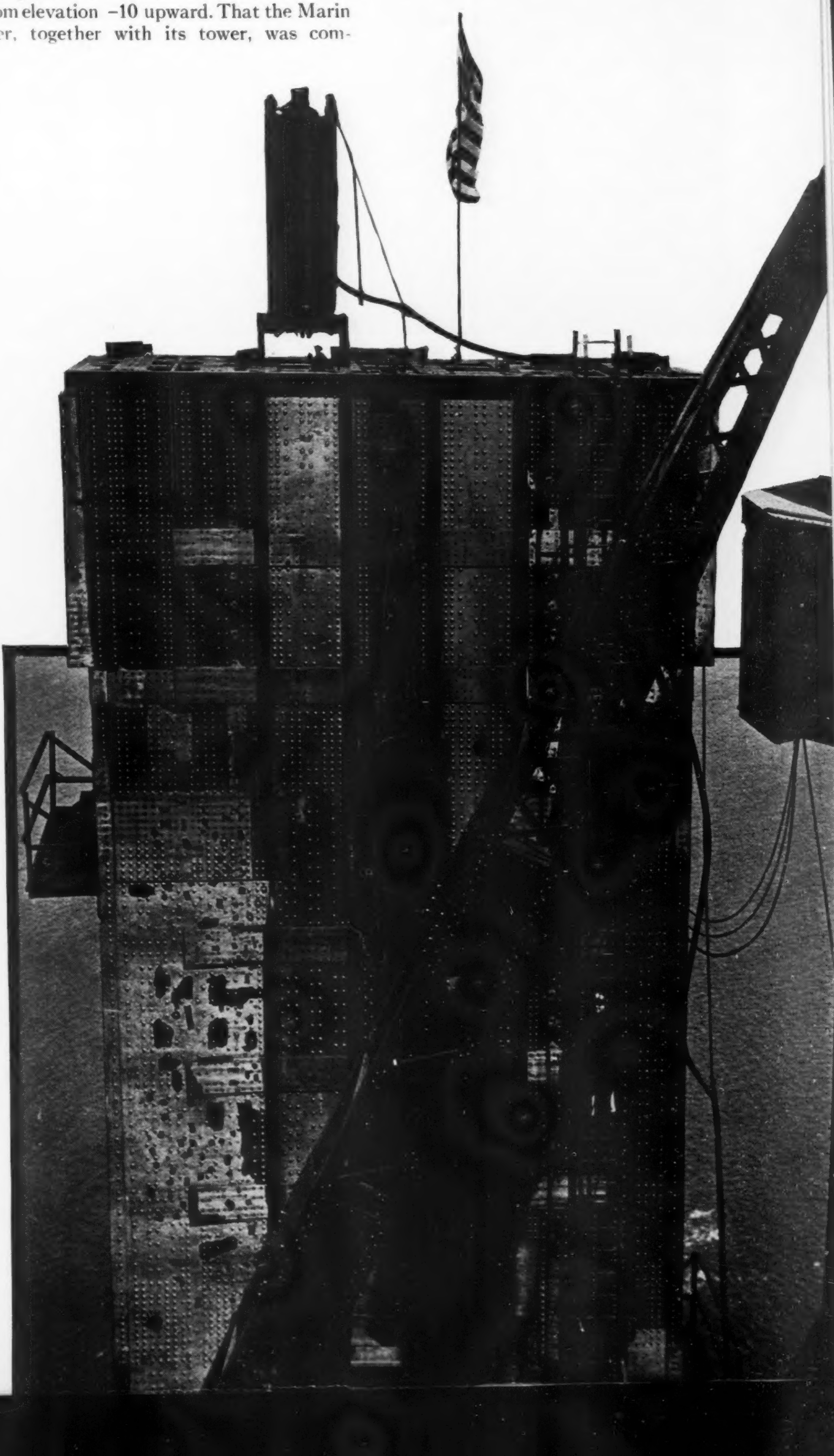
The main piers were built by the Pacific Bridge Company at a cost of $2,935,000. The Marin pier, which was the first to be taken in hand, has a base block 80x160 feet in plan and 10 feet thick, with footings at elevation –20. The main shaft is solid, 54 feet high, and has battered sides sloping from 72½x149 feet at the bottom to 65x134 feet at the top. Above the water line it is treated architecturally to harmonize with the superstructure. A 177-ton mat of reinforcing steel, consisting of 1¼-inch bars assembled in four layers, distributes the load imposed by the twin towers.

Before operations on the Marin pier could be started, it was necessary to construct a 2-lane road along the base of a precipitous cliff for a distance of 1,700 feet, 400 feet of which is carried on a trestle, and also an open cofferdam around the pier site. Although in relatively shallow water, the sweep of heavy waves complicated the latter work well-nigh continually. A crawler crane was used to drive the sheet piling and traveled on a trestle about 10 feet in from the outer wall of piling.

Where exposed to the action of the waves, the piling was reinforced by 60-pound rails carrying a wale well braced to resist both the water pressure and the outward pressure of the rock and other diking material. These rails were driven into 5-inch holes drilled into the piling on 6-inch centers by a submarine drill handled by a crane. In one corner, where there was loose rock to a depth of –34, two heavy timber cribs were sunk. These were 34 feet wide, the longer one having a length of approximately 60 feet. The seaward side of these abutting cribs, which topped at elevation –2, served as wales for the sheet piling.

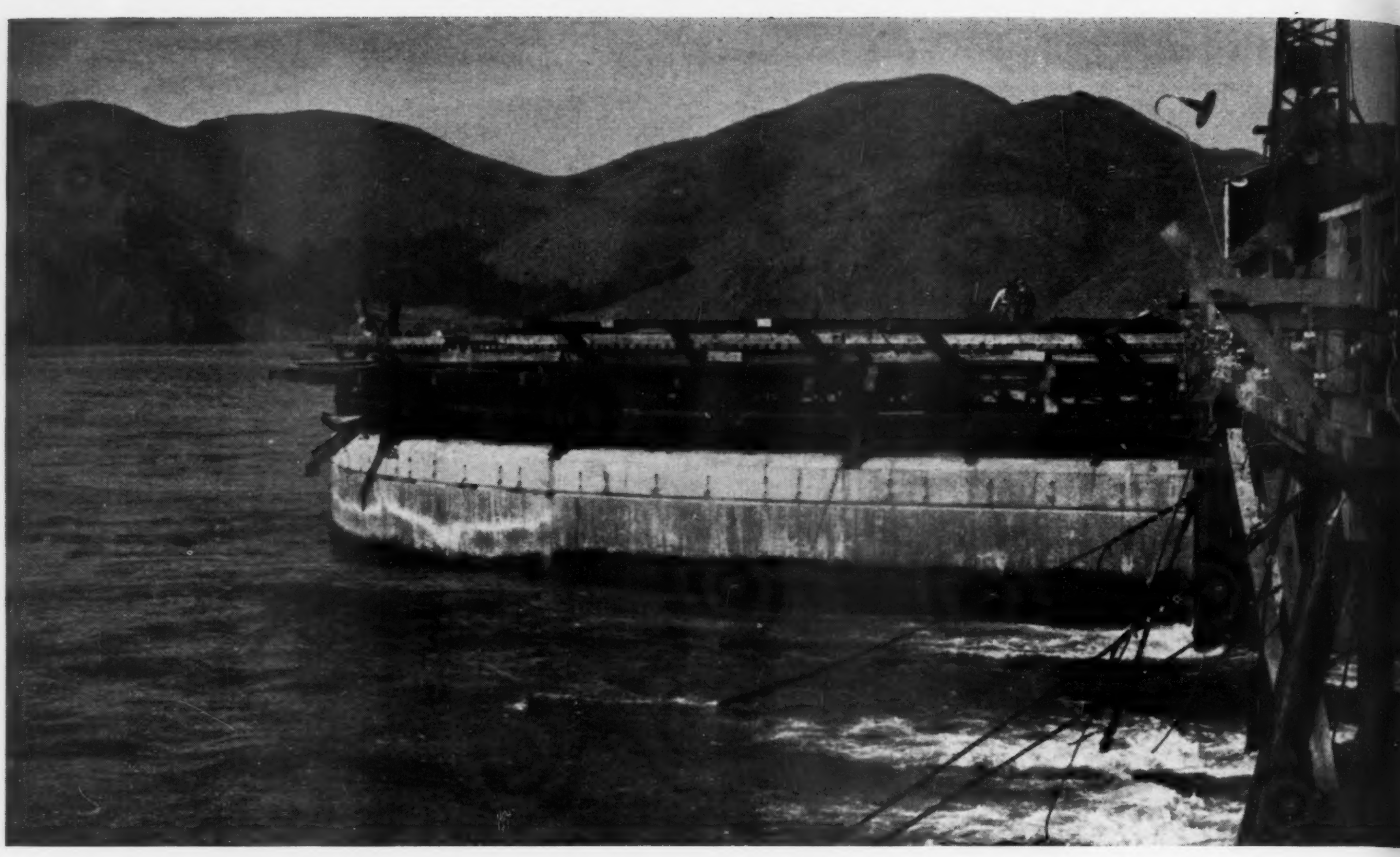
During the earlier stages of pier construction, the pumps had to handle an aggregate of 12,000 gpm., but leakage gradually diminished by reason of silting. The contract specified that the concrete be carried upward continuously for a distance of 33 feet, starting at elevation –11. This meant the setting up of considerable lateral pressures, which were counteracted by double 3x16-inch wales on 6-foot centers on the outside of the forms and tied together with 1¼-inch rods. A 100-foot Insley mast hoist with a 1-cubic-yard bucket made it possible to reach any part of the pier throughout the building period. Two 103-ton tower anchorages were embedded in the pier, one at each end, and extended from elevation –10 upward. That the Marin pier, together with its tower, was completed ahead of schedule is commendable.

The south or San Francisco pier presented a far more difficult construction problem by reason of its exposed position and the great depth to which it had to be sunk. The sloping shelf of serpentine at the site carried no overburden and lay at elevations ranging from –52 to –87, necessitating a footing at elevation –100. To facilitate the building of this pier and to give it increased stability, as well as to protect it from shipping and pounding seas, a generally oval-shaped reinforced-concrete fender was constructed to encircle it. This fender is a permanent feature of the pier. It is 300 feet long, and has



TOPPED OUT

At eleven o'clock in the morning on May 4, 1934, steelworkers placed atop the Marin tower the flag with which they traditionally signalize the completion of their work on any lofty structure. This tower rises 746 feet above mean high water. Its mate on the San Francisco side is scheduled to be completed next July. Beside the flag is a pneumatic hammer which was used in the erection work.



a maximum width of 155 feet and a wall thickness of 27½ feet.

The preliminary work at the south end of the bridge was started in January, 1933, with the building of a 22-foot wide trestle from Fort Point to the pier site. As planned, this structure was to be supported on wood pile bents placed on 30-foot centers. But after ten had been driven it was proposed to drill 14-inch holes with "Calyx" drills to receive pipe sections into which steel columns were to be grouted. The friable character of the rock, however, prevented holding the holes to size and withdrawing cores, so penetration was effected by the unique method of repeatedly dropping in one spot a 20-foot steel spud carrying pipe-encased bombs charged with varying amounts of dynamite. These bombs and their method of application are described in the preceding issue of this magazine.

Because much of this work had to be done during relatively brief slack-water periods, progress was greatly retarded. In fact, just ten months elapsed from the time it was begun until the placing of the 20-ton fabricated-steel sections for the fender was taken in hand in November, 1933. On October 31, heavy ground swells wrecked the 100-foot-high guide tower that was designed to lower those sections, seriously damaging the trestle. A subsequent storm virtually destroyed all the trestle except the ten bents on the wood piling.

In its initial form, the guide tower was 30x8 feet in plan and 100 feet high. Weighing 50 tons it was delivered by a barge, upended, secured to the outer end of the trestle, and guyed with steel lines anchored to pipes driven into blasted holes. Its four legs were concreted in 26-inch-diameter steel tubes. After the aforementioned storm, the tower was salvaged and lengthened 20 feet, and its base was embedded in a block of concrete, 20 feet thick, set in rock excavated to a depth of –95 feet.

As originally planned, the fender, which consists of 22 sections each 33 feet long, was to be built up from the sloping rock bottom by successively placing one above another and filling with concrete six or less (the number depending upon the elevation of the underlying rock) somewhat standardized boxlike structural-steel units each 20 feet high, 33 feet long, and 27½ feet wide. However, it was decided to carry the fender footings to approximately the same elevation as those of the pier—that is, to –100, thus giving the fender a height of 115 feet. Furthermore, it was deemed advisable to excavate as nearly as possible to that depth before bringing in the mammoth pneumatic caisson to be used in the construction of the pier so that it would not be necessary during the process of hand excavating to resort to the slow and hazardous alternative of lowering the caisson some 52 feet with sand jacks on those sides not engaging rock. The work was done by the bombing method, and the broken rock was removed by a floating dredge.

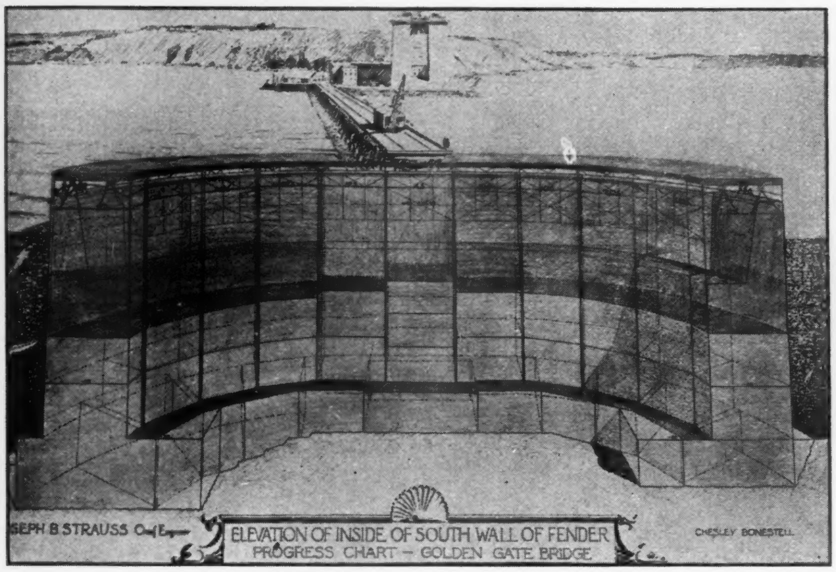
Because of difficulty experienced in providing sufficiently accurate data that would permit fabricating the lowermost steel units of the 22 fender sections so that they would conform to the contours of the rock, these units were made up on location by the use of a 45-foot-wide cage of 18-inch I-beam wales. To this frame divers clamped wood panels—the cage and panels being used successively. The flaring base so poured extended 10 feet in from the inside wall line of the fender and as far out from the outer wall line as the rock slope would allow.

The initial fender section was constructed by sliding down the guide tower on rails the several structural-steel units required. These, together with the material and equipment needed for concreting by the tremie method, were first handled by a Whirley mounted on the trestle and, later, when the growing fender assured a suitable foundation, by two Whirleys on a platform surmounting the fender at elevation 25. Crane rails riveted to the ends of the 33-foot units provided a means of sliding down adjacent fender sections, thus virtually interlocking the heavy steelwork throughout. Mats of reinforcing steel were secured by divers. As a section was placed it was filled with concrete—the entire structure being built up in this way to elevation –41 to –38.

In concreting from that point upward, steel bents, erected on the concrete and connected to the steelwork below, served as end frames; precast panels of reinforced concrete were employed as outer wall forms up to elevation –6; and panels of creosoted timber were used on the inside up to eleva-

CONSTRUCTING THE TOWER FENDER

The building of the concrete structure which incloses the pier for the San Francisco tower was a herculean task, because it had to be carried upward through 100 feet of water that has a tidal surge as great as seven miles per hour. The drawing below shows half of the twenty-two 33-foot sections of which the fender is composed. The shaded line at about mid-height is at elevation –41 to –38, to which points the several sections were brought up one at a time before concreting was continued.



tion –15. Side frames of 8-inch beams disposed vertically on 6-foot centers along both faces of the bents permitted sliding the panels into position, while rails on the column faces assisted in guiding them. The form for the outer face of the fender between elevation –6 and elevation +15 was a 33-foot-long panel of creosoted 6-inch timber that was clamped to the side-frame wales at its lower edge and drawn with cables against the concrete panels at elevation –6. The inner form consisted of sloping panels 8 feet wide made of 6x12-inch timber and 3x12-inch sheathing. With the lower end drawn against a steel wale at elevation –15, it was supported at elevation +3 by a steel truss with brackets and hook bolts. Tongue-and-groove sheathing and studding served above elevation +4, while end forms were made by inserting steel or concrete panels between the permanent 8-inch guide beams.

Early in September, 1934, all but eight of the fender sections had reached elevation 15. This gap had been left purposely to permit the entrance of the 90x185-foot pneumatic caisson built on the ways of the Moore Dry Dock Company for the construction of the pier. This caisson had fifteen compartments in its working chamber and was the largest of its kind ever assembled. On October 8, it was towed down the bay and moored inside the fender. On the following day heavy seas caused it to pitch and roll to such an extent as to break its mooring lines and to crush the floats acting as buffers between it and the fender. That same evening the caisson was removed, and it was decided to use the fender as a cofferdam in which to build the pier.

Steps were promptly taken to repair the damage done and to complete the fender. It was then divided into seven transverse compartments by timber bulkheads. These were made in two sections, set one above the other, and served as forms in pouring the footing course between elevation –100 and –65. Two bulkheads, with heavy transverse bracing between them, constituted a complete assembly, the intervening space being subsequently filled with concrete which was tied to the contiguous blocks by 6-foot keys. Concrete was poured continuously by the tremie method between the elevations given, and varied from 3,000 to 4,000 cubic yards in each of the several compartments. With the first course completed, a mat of reinforcing steel was laid on top of it; the bulkheads were set up so as to stagger the joints; and the second course was poured to elevation –35.

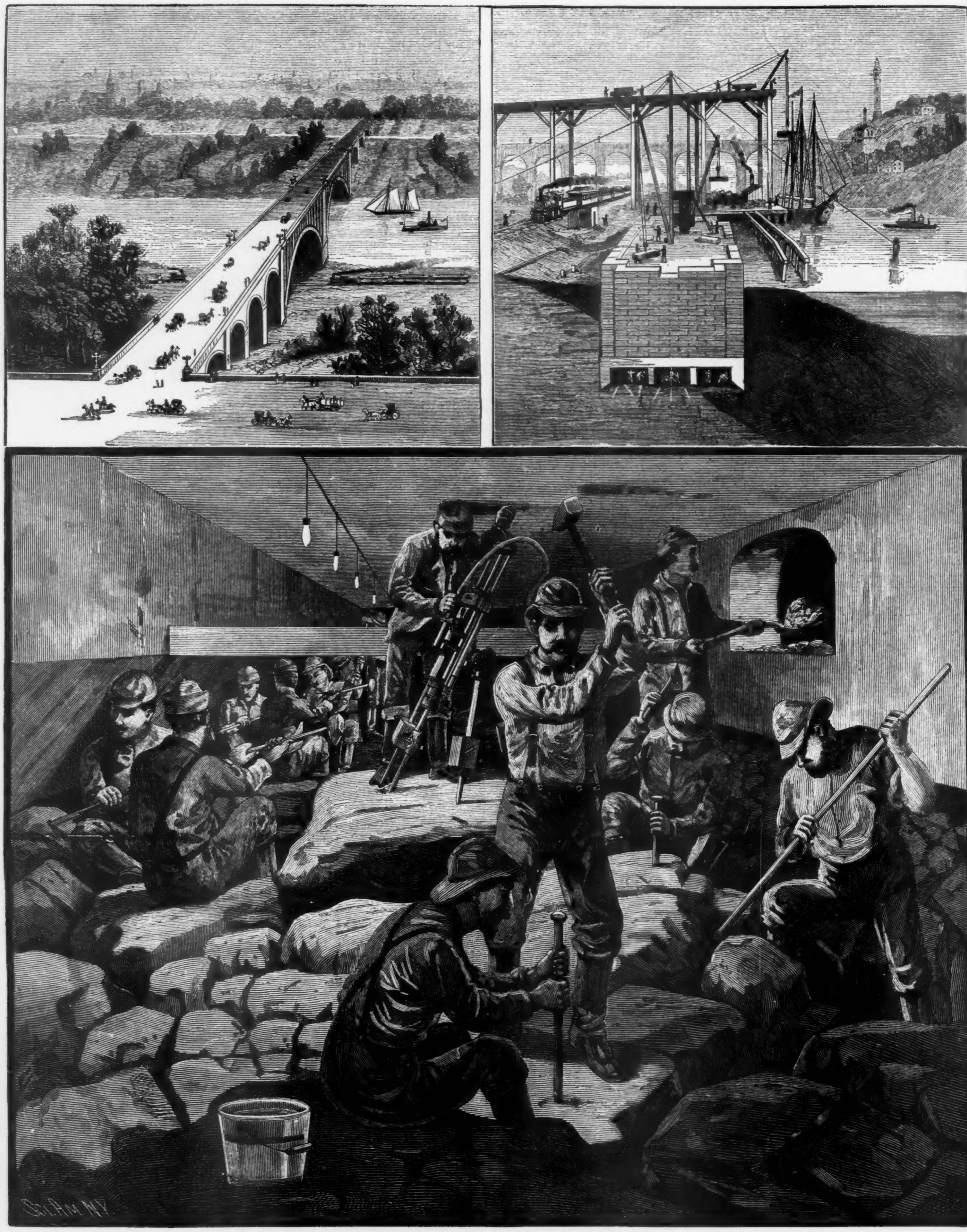
For inspecting the rock beneath the lowermost course, there were provided eight 15-foot-diameter steel domes spaced equidistant and connected with the surface by 30-inch steel pipes. Later, an air lock and decompression chamber were employed in conjunction with these pipes to inspect and to photograph the concrete.

The footing of the pier shaft proper is at elevation –35. At that stage in the operations the fender was pumped out, forms were set up, and concrete poured in much the same manner as in the case of the Marin pier. A small pump working intermittently took care of leakage after the dewatering of the cofferdam. The base of the San Francisco pier batters from 185x90 feet at elevation –35 to 140x70 feet at sea level. The structure is lightened by a roofed-over open well 46x36 feet in plan and extending from elevation –45 to +32.

Work on the south pier is finished and the erection of the steel tower is in progress —the companion tower, on the Marin shore, being ready to receive the cables. The contract for the fabrication and erection of both of the main towers, floor system and bracing, and 3,500 tons of girders and eyebars for the anchorages, was awarded to the McClintic Marshall Corporation, of San Francisco, on a bid of $10,494,000. Rising 702 feet above their pier tops at elevation 44, each of the towers calls for the use of 22,200 tons of steel and has an over-all width of 121 feet at the base. It is in the form of a pair of posts each composed of a series of rectangular cells arranged in groups—the number of the cells decreasing from 97 at the bottom to nineteen at the top. Instead of the customary network of transverse bracing between posts, the towers are portal braced, giving them the effect of imposing doorways. In this respect the bridge is said to be distinctive, as well as in the matter of the stepped-off design of the towers.

As soon as the south tower is completed, the assembling of the main cables will be started by pulling a suitable line across the bay with a tug. This will be used to haul over four cables that will be swung into position high aloft on temporary saddles and serve to carry temporary footbridges. From these aerial stations men will install and operate the cable-spinning machinery —in effect, endless cables that will run the length of the structure on sheaves and be provided with devices for pulling the multiple wires that constitute a cable from anchorage to anchorage. Each will be made up of 27,572 separate wires, or 55,144 all told which, if laid end to end, would be long enough to girdle the globe more than three times. Likewise from those lofty walkways will be operated the great hydraulic presses which will squeeze the wires into the compact cables that will have a load-supporting capacity of 430,000,000 pounds, or 2.6 times the maximum load. The contract for supplying and placing the main cables, suspender ropes, etc., is held by John A. Roebling's Sons Company on a bid of $5,855,000.

The Golden Gate Bridge engineering organization consists of Joseph B. Strauss, chief engineer, and O. H. Ammann, Charles Derleth, Jr., and Leon S. Moisseiff, consulting engineers. Clifford E. Paine is principal assistant engineer and Russell G. Cone is resident engineer. We are indebted to *Western Construction News* for the data covering the building of the San Francisco pier fender.



CAISSON WORK 48 YEARS AGO

Immediately above, workmen are shown within one of the three compartments of the timber caisson that served in sinking the central pier for the Washington Bridge across the Harlem River in New York. The tripod-mounted Rand rock drill was the first ever employed in an excavation made under air pressure. This also was one of the first instances in which incandescent electric lamps were used on a construction job, arc lights having been utilized for some time previously. At the upper right is a sectional illustration of the caisson with Highbridge, built in the 1830's, in the background. The completed bridge is shown at the upper left. Both sides of the Harlem River at this point are now thickly built up.

Old Prints Show First Power Drill in Caisson

THE illustrations on the opposite page, which are reproduced from the *Scientific American* of April 16, 1887, show the methods that were used in sinking a caisson for one of the piers of a bridge across the Harlem River at 181st Street in New York City. This was the first construction job on which a power-actuated rock drill was employed in excavating under pressure by the aid of a pneumatic caisson.

The bridge is known as the Washington Bridge, but is not to be confused with the George Washington Bridge across the Hudson River which has its Manhattan end only a few blocks away. After 47 years of service, the Washington Bridge is still in excellent condition, and daily carries a huge volume of automobile, street-car, and pedestrian traffic. The superstructure has been repaired and modified from time to time to enable it better to meet the continually changing demands imposed upon it; but the supporting members remain exactly as they were when built. From all outward appearances, the structure will last indefinitely.

The bridge extends from Amsterdam Avenue in Manhattan to University Avenue in the Bronx. It has a total length of 2,375 feet. There are two main metal arch spans, each 510 feet long. On either side of them are approach arches of granite masonry. Each of the two central spans is composed of six steel-plate members spaced 14 feet apart and connected with bracing. The bridge cost $2,889,586. It was begun in July, 1886, and completed in February, 1889, but was opened to traffic in December, 1888. William R. Hutton was chief engineer in charge of construction, with William J. McAlpine and Theodore Cooper the consulting engineers, and Edward H. Kendall the consulting architect. Alfred Noble and John Bogart served successively as resident engineers. The Passaic Rolling Mill Company and Myles Tierney were the general contractors.

The caisson was used in constructing the east or Bronx shore pier of the span which crosses the river proper. This pier was carried to a depth of 45 feet below the water's surface. Borings showed that rock lay at a depth of 15 feet along the eastern side of the pier site and sloped sharply toward the center of the stream. This rock was covered with a thick overburden of mud and silt which constituted the river bed. Because of these conditions, the caisson, during much of its downward course, rested partly on rock and partly on soft, water-bearing material. As there was a strong tendency for it to shift riverward with the slope of the rock, extreme care had to be taken to sink it vertically. According to an account of the work which accompanied the pictures, more explosive was employed on this job than on any previous undertaking of a similar character. Following are excerpts from the *Scientific American*:

"The caisson was designed, and the foundation built, by Messrs. Anderson & Barr of New York. The bottom of the caisson measures 54x104 feet, the dimensions of the top being one foot less. The roof is six feet thick and is built up of pine timbers one foot square laid in courses running in different directions. The side walls are three feet thick, and are also made of timbers one foot square; the outside and inside courses are horizontal, while the intervening course is vertical. The inner lower portion of each wall is beveled off to form a cutting edge, which is nine inches wide and is protected by an oak strip. The outside of the walls is covered with a 3-inch sheathing, and the entire interior is sheathed. From the bottom of the shoe, or cutting edge, to the top of the caisson is thirteen feet, and the interior is seven feet in height from shoe to ceiling. The chamber is divided into three compartments by two longitudinal partitions which are two feet thick by five feet high and in which are formed suitable openings that serve as passageways. The bottoms of the partitions and of the side walls are connected by heavy timber struts and iron tie rods.

"In the center of the roof is placed the supply lock, through which all excavated material is passed and all supplies received. The lock for the men is placed at the top of a shaft extending through the roof, a ladder furnishing the means for ascent and descent. This lock is twelve feet long by four in diameter, and is provided at each end with a chamber closed by two doors opening inwardly. As this forms two independent locks, no time is lost in waiting, as one lock may always be entered from the interior and the other from the exterior. Eight or ten men can crowd into one of these locks.

"On account of the rock, the method of sinking the caisson was somewhat different from that usually followed. In the solid rock under the shoe, and in the large fragments, the holes were drilled by hand; but in the center of the chambers the drilling was done by a Little Giant drill, of the Rand Drill Company, which was tripod mounted and supplied with air at 80 pounds pressure.

"After a blast, the loose rock was removed from under the shoe, and earth was put in its place. When all the rock under the edges had been removed to a depth as great as it was practicable to go at one time, and earth had been packed under the shoes, the caisson was in condition to be sunk, as it was supported wholly by earth. The earth was removed, a little at a time, at intervals around the entire shoe, and the caisson gradually settled down. Its downward progress was closely watched, four stakes, one at each corner, forming guides that indicated the settlement; and if one side advanced more rapidly than the other, the earth was repacked under its shoe, so as to offer more resistance and retard that side. In that way the caisson was sunk vertically, and so truly and evenly that, when it finally rested upon its bed, the four corners and the center did not vary an inch from being in the same horizontal plane.

"As the caisson descended, the masonry of the pier was added on the top. This furnished the weight necessary for overcoming the friction upon the outside. After the structure had been carried down so that almost the entire shoe rested upon solid rock, the rock was cleaned of all debris and the three chambers completely filled with concrete, the filling being started at the corners and carried toward the shafts."

WASHINGTON BRIDGE TODAY

In excellent condition, this structure still carries heavy traffic daily. Its roadway is 150 feet above mean high water. The pier which shows most prominently is the one that was sunk by the caisson method. It forms the central support for the two main spans.

This and That

In the Realm of Old Rip

Until a few weeks ago officials and employees of the Palisade Interstate Park along the Hudson River were baffled by the thunder of mysterious explosions in the mountain fastness of the Catskills where Rip Van Winkle took his long siesta. They were unable to locate the origin of the reverberations; but one day they came upon a fresh scar in the rock of a mountainside, and nearby they found some rock drills, other tools, and a quantity of dynamite. They confiscated these and maintained a watch in the area. Nothing happened for a long time, save that the explosions were heard no more. Then one day four men were observed trudging up the hillside carrying a miscellaneous assortment of tools. They wouldn't explain what they were about, but on each was found a copy of an agreement binding him to turn over any treasure he might find to four men whose names were signed at the bottom of the paper. Confronted with these documents, the men admitted that they had been hired to search for bars of silver and barrels of dollars which, so a musty legend has it, was secreted in a cave somewhere in the section. The whole expedition was based on a map which was reported to have been found in the Morgan Library in New York City. One of the signatories of the agreement was located, but he denied all knowledge of the matter So far the mystery has not been solved, but the blasts have ceased.

★ ★ ★

Fossil Enigma Solved

Certain small fossils which are abundant in Montana and which have been accepted for nearly 80 years as the teeth of prehistoric fishes have been proved to be nothing more formidable than the remains of ancient worms. This revelation, which is considered highly important by paleontologists, was made by Harold W. Scott, of the Montana School of Mines, following a 2-year study.

The fossils, termed "conodonts," were discovered in 1856, and have been of great practical use to geologists by serving as a positive means of identifying certain formations in which they occur. They are only about one twenty-fifth of an inch long, but bear such striking resemblance to teeth of the shark family that they were assumed to have come from diminutive fishes which were believed to be forbears of the modern shark. Many scientists were skeptical of this classification, but repeated investigations failed to produce a more plausible one until Mr. Scott attacked the problem. His explanation of the true origin of the tiny fossils is in entire accord with other evidence bearing upon the past history of the formation concerned, and has effectually cleared up a vexing question.

★ ★ ★

Russia's Mineral Wealth

According to a recent report to the Soviet Government by Professor Zaharoff, the far eastern provinces of Russia contain vast mineral riches. Coal reserves are estimated at 200,000,000,000 tons, and iron deposits at 2,000,000,000 tons. Other resources include oil and rare metals, precious stones, and, to quote the report, "millions of tons of other minerals." The provinces surveyed are equal in area to eleven countries in western Europe. These surveys are said to have been conducted with great scientific care and to have cost millions of rubles.

★ ★ ★

Balkan Gold Boom

The appreciation in the price of gold has restored the profit possibilities of Balkan gold fields of such ancient discovery that they were worked in turn by Alexander the Great and by the Romans. One of these properties, on the River Pek in northeast Serbia, is yielding gold at the rate of $1,000 a day. A second mine is crushing 40 tons of ore daily and produced 4,000 ounces of the precious metal in 40 weeks.

Probably no gold field in the world has a more romantic history than this one in Serbia. The workings of the early Roman miners are found in abundance: the primitive sleds which they used for transporting ore and spoil still lie about, well-nigh buried under centuries of debris.

Shortly before the World War, a German mining engineer discovered a gold-bearing vein in northeastern Serbia. He worked some of the richer pocket deposits and opened up an adit from which several thousand tons of ore was taken. But before a stamp mill could be erected, Serbia became a battlefield and all operations had to be suspended.

Odd contrasts are presented now, for alongside the most modern plants one sees ox-wagon transport, exactly as in Roman days, while peasants may be observed washing the river gravels for the precious metal by immersing in the water sheepskins which catch the flecks of gold.

Well-posted authorities hold the view that the best gold-bearing areas in Jugoslavia have not yet been touched, and that a Balkan gold boom is within the realm of possibility. Already an extensive prospecting program is being arranged; and three new veins have been discovered in one mine.

★ ★ ★

Manifold Uses of Centrifuges

The principle of centrifugal force is being put to many new industrial applications and is commanding increased attention from scientists and engineers. A recent experimental achievement along this line was the construction, by Dr. J. W. Beams of the University of Virginia, of a diminutive centrifuge which attained the amazing speed of 1,200,000 rpm. The tiny rotor was spun by streams of hydrogen impinging upon its flutings through holes in the stator. Once it got up speed, it rode upon a film of hydrogen without lubrication. It was computed that, at top speed, it exerted a force 7,600,000 times greater than that of gravity. Under the influence of such a force, a pinhead would weigh 250 pounds. At the speed mentioned, the 3/8-inch rotor, could it have been laid on its side, would have rolled along at the rate at 1,390 miles an hour.

An article in *Oakite News Service* calls attention to some of the principal industrial applications of centrifugal force. One of the oldest is exemplified by the cream separator, and another in the drying of clothes in laundries by spinning them at about 500 rpm. Some commercial centrifuges operate at speeds up to 15,000 rpm., at which they generate forces upwards of 13,000 times those exerted by gravity.

Thousands of individual services are performed by centrifuges, but the chief ones may be grouped under the following five heads: Clarification, that is, the removal of suspended solids from fluid and semifluid substances; dehydration; recovery of liquids from emulsions; recovery of solids from suspension, which differs from clarification in that the object is to secure the maximum yield of solids; and regeneration of used liquids.

★ ★ ★

Longest English Word

Holding its annual meeting in New York, the National Puzzlers League sprung upon the unsuspecting public a tongue-twisting word of 45 letters that easily qualifies as the longest in our language. The word, which is held to be practically unpronounceable, even by a sober person, is pneumonoultramicroscopicsilicovolcanokoniosis. The first four letters classify the attenuated monster, and indicate that it relates to pneumatics, which gives sufficient warrant for sprawling

it across this page. As befits its prodigious proportions, the word connotes something decidedly unpleasant. It is the designation for a special form of silicosis of the lungs which may become contracted by breathing air laden with ultramicroscopic particles of siliceous volcanic dust. The new champion supplants antidisestablishmentarianism, a mere midget of 28 letters.

★ ★ ★

Hidden River Valleys

To talk of rivers that flow unseen sounds a bit eerie, yet it is well known that such streams are not at all unusual. At the present time, the City of Rochester, N. Y., is considering drawing upon one of them for its municipal water supply. As time goes on, and urban sections become more congested, it may grow to be the conventional procedure for engineers to probe for underground flows near at hand before turning to surficial sources that are far afield.

According to Prof. H. L. Fairchild of the geology department of the University of Rochester, the Genesee River and its tributaries once flowed in deeply carved canyons. Then the glaciers filled the depressions with silt and bowlders, and it is on top of these deposits that the streams now run. In its lower reaches, the Genesee leaves the channel in the old gorge entirely and follows another course to Lake Ontario. However, there is still a strong percolation through the permeable ground in the preglacial canyon, resulting in a sizable buried river. From studies which he has made, Professor Fairchild estimates the underground flow at 1,427,526,838 gallons daily, which is equal to Rochester's consumption of water in six weeks. Two wells which tap this subterranean stream have been pumped for a considerable period and have maintained deliveries of 700 gpm.

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Uses of Fast Movies

High-speed motion-picture cameras may become standard equipment wherever it is desirable to analyze mechanical motions which are too rapid to be followed with the eye. Experiments indicate that they will have great practical value in various branches of engineering. Surprising and important variations in velocity, acceleration, and deformation of moving objects are clearly revealed by the films.

The procedure is to operate the camera at several times the normal projecting speed, which gives the effect of slow motion when the film is projected at the usual rate. For instance, if an action requiring one-tenth second to complete is photographed at the rate of 1,600 frames per second, and is then viewed at the normal projection speed of sixteen frames per second, it will be depicted as lasting 100 times as long, or ten seconds. Furthermore, the apparatus and technique have been developed so highly that it is possible to obtain individual frames of sufficient clarity to permit their being enlarged for the study of details.

Such a high-speed camera has been devised at the Massachusetts Institute of Technology and is fully described by H. E. Edgerton in *Electrical Engineering* for February. That the machine has extra occupational uses of wide interest is evidenced by an analysis of a golf stroke accompanying that article. Pictures taken at the rate of 960 per second furnished a basis for calculations, which disclose the mechanics of the stroke in detail. In the case in point, the club head was found to be moving at the rate of 151 feet per second, or 103 miles per hour, just prior to its impact with the ball. The velocity imparted to the ball was 186 feet per second, or 127 miles per hour. The spin of the ball was computed to be 5,000 rpm.

★ ★ ★

FROM KITCHEN TO TABLE VIA PNEUMATIC TUBE

IN THIS era of robotism, more and more things are being done for us mechanically. Although it took inventors a long time to get around to the domain of the housewife, they have since then made rapid progress in lightening domestic labors. From Germany there now comes word of a scheme which not only relieves the *Hausfrau* of the necessity of cooking but which actually makes it possible for her to serve meals at home without entering the kitchen or even having one to enter.

This rather amazing feat is accomplished by means of a pneumatic-tube system that delivers hot meals to the home from a central kitchen. The first installation of the sort has been so well received that others are said to be certain to follow; and some alarmed *bon vivants* are fearful lest Berlin women forget entirely the art of cooking, for which they have been famous.

Service of this kind is now available within a radius of ten blocks from the supply point. From there, pneumatic tubes extend to every apartment house in the area. The system, from the housewife's standpoint, is simplicity itself. A glorified bill of fare, which consists of 300 pages and resembles a telephone directory in size and make-up, is distributed to each subscriber. It lists virtually every dish which appeals to the palate. In planning her menu, the lady of the house goes through this booklet, and when she has decided what she wants she telephones her order, specifying the hour of delivery. She can wait until near meal time, for 15-minute service is obtainable.

At the kitchen, the different courses are placed in separate thermos bottles. These are inserted in corrugated containers and are then ready to be whisked to their destination by means of compressed air. The kitchen is, of course, a huge affair. There are cooked not only many varieties of food but also huge quantities of certain staple dishes. These are prepared in long, galvanized-metal troughs. Pots are used for the viands which are in lesser demand.

If this scheme retains its present popularity, future Berlin homes and apartments may be built without kitchens. Instead, in a closet adjacent to the dining room, there will be pneumatic-tube outlets from which a meal can be produced in a manner that smacks of a magician pulling white rabbits out of a top hat.

Globe Photo

EDITORIAL

"LIFE BEGINS AT FORTY"

WITH this issue, COMPRESSED AIR MAGAZINE enters upon its fortieth year of publication. It was established in March, 1896, as "A monthly publication devoted to the useful application of compressed air." The founder's salutation expressed the belief that "the development of the science of compressed air has suffered for want of publicity. Discussion, controversy, advertising," he wrote, "all lead to a better knowledge of the subject and point the way to larger fields of usefulness. Thus far the subject has been treated in only a fragmentary way. An occasional book, lecture, essay, and article in trade papers have been the extent of its promotion."

It is of interest to note that the MAGAZINE retains its unique position of being the sole periodical devoted primarily to the advancement of compressed air and its application, although that adaptable power medium has come into such widespread employment that its accomplishments are recorded from time to time in the literature of many industries.

At the start, the publication was called simply *Compressed Air*, and the word "magazine" was not appended until October, 1908. In its initial format, it was 5½x 8¼ inches: in ten years it outgrew its clothes and was given a 6¾x9¾ size. Again, in 1920, it was enlarged to its present dimensions. Concurrently with its physical growth its scope has widened until it now touches upon "the many fields of endeavor in which compressed air serves useful purposes."

The publication was established by William Lawrence Saunders, who later rose to eminence in the compressed-air equipment manufacturing industry. While a student in the University of Pennsylvania, he edited the school magazine and, upon his graduation in 1876, took up newspaper work. Two years later he turned to engineering. One of his first engagements was that of marine engineer in New York Harbor. In the course of his activities he had need for underwater drilling equipment, and his investigations in that field led to his subsequent industrial career. Nearly twenty years after he had forsaken journalism, his flair for writing again found a medium for expression with the founding of this MAGAZINE.

"Compressed air, as a useful power, demands attention," Mr. Saunders wrote in his first issue. "Its scope of usefulness is each day widening, and its possibilities are beyond conjecture." Compressed air has received the attention which he claimed for it. Otherwise his words are still as true as they were when he set them down. Compressed air is finding new applications all the while, and its possibilities remain beyond conjecture.

CRUSHING BY EXPLODING

IT IS difficult for the layman to comprehend that many of the world's gold mines reap their profits from ore which runs well below one ounce of gold to the ton. To persons who are not familiar with the procedure employed, it seems unbelievable that such an insignificant amount of metal can be wrenched from the grip of its encompassing rock. When they are informed that single properties handle thousands of tons of ore daily with a recovery of well over 90 per cent of the contained gold, their awe passes the limits of concealment.

The technological advances in metallurgy do, in truth, constitute an inspiring story of progress. It is a story that continually grows longer and more interesting. Milling experts have beyond doubt "made" many mines; and, with the mounting price of gold, their importance increases apace. A saving of an additional per cent of metal represents thousands of dollars more in annual income from a large mine. A reduction in costs of milling is equally important.

Great interest therefore attaches to the announcement last month before the American Institute of Mining and Metallurgical Engineers that a new and less expensive method of crushing ore has been devised. In this process use is made of the novel expedient of breaking the mineral particles by means of exploding superheated water. Steam at 150 to 200 pounds pressure is admitted to a vessel containing ore. Some of it condenses, forming a thin water film on the mineral. When the pressure is reduced, the hot water flashes into steam so suddenly that it explodes and shatters the rock. According to R. S. Dean of the U. S. Bureau of Mines, who reported upon it, the new method appears to be practical and promises to cut 20 per cent from the prevailing cost of pulverizing ore.

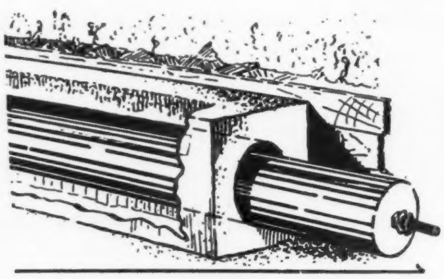
DEFEATING FOG

GREATER safety in the navigation of ships during foggy weather is promised through the development of a means for intensifying the light from ordinary marine electric lamps. By using special optical devices, and by increasing the voltage above the normal rating, a 50-candlepower lamp can be made to produce as much as 500,000 candlepower. Such a light will penetrate a medium-density fog three times farther than those in service today, and will assure visibility that far. These facts were revealed recently by Gjon Mili, an engineer with the Westinghouse Lamp Company.

A medium-density daytime fog is described as one in which an object may be seen at a distance of approximately 400 feet. Used in such a fog, a marine signal with a 50-candlepower lamp increases the visibility to 800 feet. The method advanced by Mr. Mili would, it is declared, further extend the range to around 2,400 feet. Because of the contrast offered by darkness, these figures would be virtually doubled at night. Application of the more powerful lamps will, it is predicted, lessen the need of ships remaining at their docks during unfavorable weather and will add materially to the ease and safety of maneuvering harbor craft at such times.

CONCRETE FORM THAT EXPANDS AND CONTRACTS

CIRCULAR openings in concrete required for a variety of purposes can be cast *in situ* by the use of a new form that is said to permit ready removal. The form is tube-shaped, of course, is flexible, and has an opening through which to admit water or compressed air. It has been introduced under the name of Flexicore by the Flexicore Company of Wichita, Kans.



When in position and inflated ready for pouring concrete, the form, by reason of the internal pressure, is increased in diameter and decreased in length. Conversely, when the pressure is released after the concrete has set, it again assumes its normal dimensions. It is this contraction and drawing away of the form from the monolithic mass that facilitates its removal. Aside from this feature it has the added advantage of being flexible so that bends and turns can be made without the use of special forms.

Flexicore is available in diameters ranging from 1 to 24 inches and in lengths suitable for the building without joints, except where needed, of telephone, telegraph, and power-line conduits, sewers, culverts, subgrade drains, and the like.

CAR BARN PUTS WASTE AIR TO USE

IN THE shops of the East St. Louis Railway Company has been worked out a scheme whereby cars are cleaned with the compressed air taken from their own storage tanks. This air has to be exhausted when cars are inspected and overhauled, and was formerly wasted—allowed to escape into the atmosphere. Now the receiver is tapped by a hose to which is attached by brake couplings a second hose that is long enough to reach every corner of the car. A nozzle made of a piece of small-diameter piping and fitted with a control valve is used to direct the high-pressure air, from which every trace of moisture is removed before application.

Heretofore, much trouble was experienced in getting rid of the dirt, bits of paper, and other refuse that collected on the floor, especially beneath the equipment in the vestibule. These accumulations absorbed moisture and caused the contacting floor boards and end panels to rot, thus necessitating frequent replacements. As a result of this economy measure the air is not only made to do useful work but the floor is swept so clean that little if any of the former repair work is required.

PLASTIC EXPANSION JOINTS IN CONCRETE BRIDGE

EXPANSION joints of sponge rubber are a feature of the railing of the new Brookpark Viaduct, near Cleveland, Ohio, which is approximately 1,920 feet long and is built of concrete. With the exception of the joints at the piers and abutments, which were left open to correspond with the joints in the floor system, all intermediate railing panels and posts were separated by a ¼-inch sheet of light-gray rubber.

In building the railing, the finished panels were set first, next the rubber was cemented to the ends, and then the adjoining concrete posts were poured in direct contact with the rubber. Apparently no difficulty was experienced in handling the plastic material, which did not extrude under pressure. The joints are said to be neat and to match substantially the color of the concrete.

The use of sponge rubber for this purpose is somewhat in the nature of an experiment; but even if it should have a relatively short service life no harm will be done because the spaces left will be smaller and the joints better in appearance than the preformed open type.

ASBESTOS MINE PROHIBITS USE OF WOOD UNDERGROUND

WOOD is taboo in the underground workings of the King Mine, Thetford, Que., of the Asbestos Corporation, Ltd., where it has heretofore had many applications. It has been condemned and supplanted throughout with concrete, steel, and other metals because of its tendency to split and splinter. The presence of wood fibers in asbestos is undesirable, for a piece as small as the head of a match in a finished product may cause its rejection, while slivers in the longer fiber used for spinning may damage the machinery handling it. It is therefore essential that the ore be free of wood, and the only way in which this can be assured is to exclude that material from the mine. It should be explained that asbestos is milled dry, and that any bits of wood in the ore are broken up with the mineral and caught and held by the fibers.

Just what this program of replacement has involved can be appreciated by examining a list of the structures, equipment, and supplies affected. It includes a 16x6-foot, 3-compartment vertical shaft, loading chutes, manways, supports, ties, and ore cars. Wooden planks have been discarded for 8-inch channel iron or reinforced-steel plate, and iron piping is being used in place of stulls for staging. Even the survey plugs are all metal. They are of the Rainboth type, on which patent is pending, and consist of a galvanized-iron casing containing a perforated lead filler into which is screwed a brass spud. Picks and shovels have metal handles, and tamping bars are made of copper tubing with a copper plug inserted in one end. Not a scrap of wood is in sight anywhere in the mine; and workers are provided with lighters because the carrying of matches is prohibited.

A MUZZLE FOR RIVET BUSTERS

AT THE Milwaukee, Wis., passenger-car shops of the Chicago, Milwaukee, St. Paul & Pacific Railway, the time-honored broom that has served there so long as a rivet-head catcher has been displaced by an improvised contrivance that is far more satisfactory. It is in the form of a wire basket without a top and with one side open for the insertion of the pneumatic rivet buster. The opposite side is reinforced by a strip of iron to prevent the wire from bulging under the impact of the rivet heads. The edges are covered with ½-inch rubber tubing slit lengthwise, mitered at the corners to assure a snug fit, and fastened with wire which is drawn sufficiently tight to embed it in the plastic material. So protected, the cage can be held against any surface without danger of scratching the paint.

The catcher is 8x8 inches in size and 3 inches deep, and is fastened to a wooden handle, 36 inches long, set at an angle of 45° to permit the helper to keep out of the way of the rivet buster and to give the latter plenty of freedom of movement and light. It also affords both men a view of the working area. This simple device will outlast many brooms, each of which cost the shop 37½ cents and was generally damaged beyond usefulness after a week's service. However, the important matter is that it speeds up the work while preventing rivet heads from flying and possibly injuring nearby workmen or equipment. It has caught and held as many as 36 half-inch rivet heads without one escaping.

Courtesy, Railway Mechanical Engineer

They used to tear down drives

low stretch and high flex life

BUT NOW YOU CAN MAKE THEM

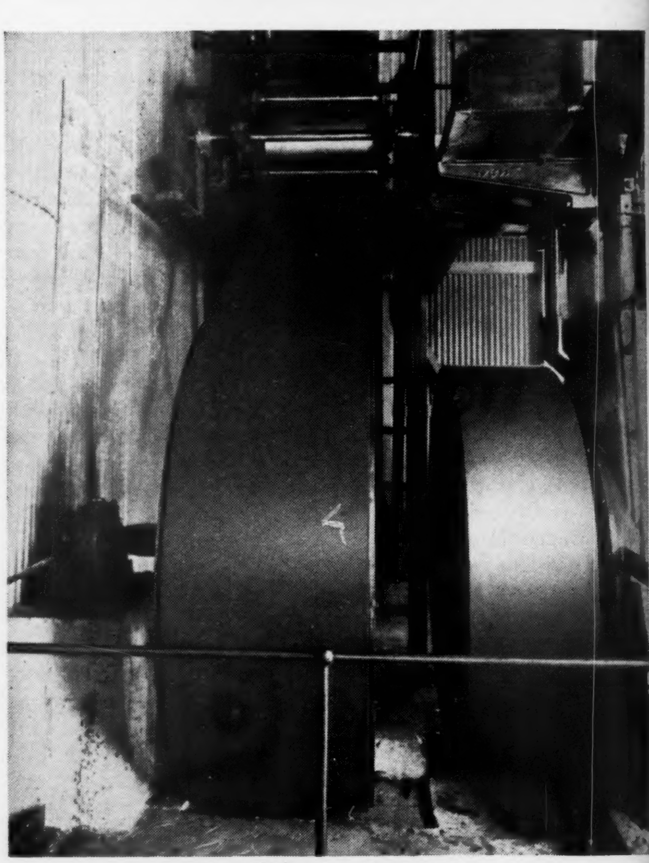
THE best proof of the savings and spectacular performance which Goodyear COMPASS Cord belts have been delivering is the trouble a wise man would take to install them.

Experience showed that—once installed—they outlasted other belts by as much as *ten to one.*

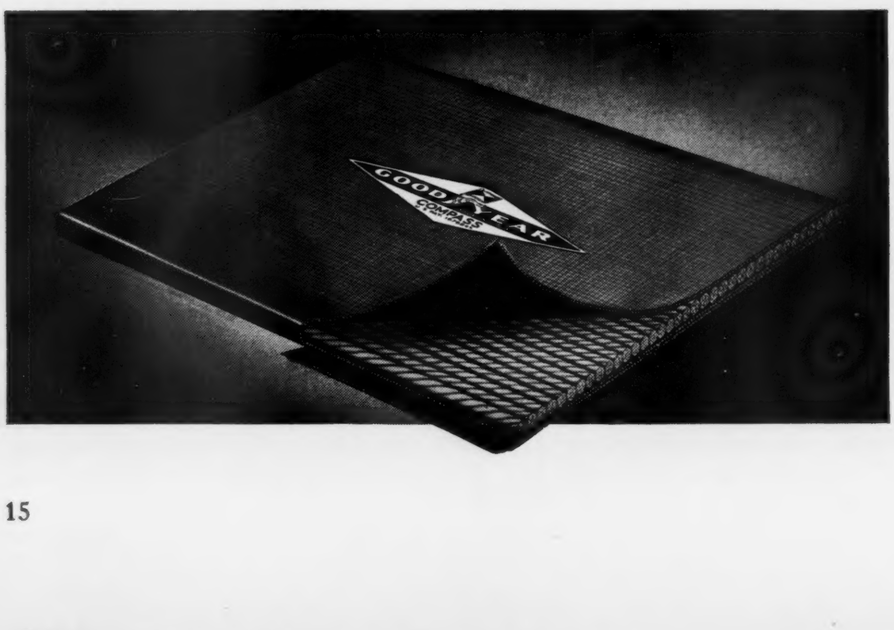
So, when necessary, plants tore down drives and tore out walls to put this money-saving belt on the job.

But the G. T. M. (Goodyear Technical Man) wasn't satisfied to let it go at that. There must be some way—he figured—to settle this difficulty—some way to install the belt so it wouldn't have to be tailor-made for every drive.

So he put the problem up to headquarters, and now we announce the answer—a *patented vulcanized splice*—with complete instructions and equipment for making these belts endless on the job.



A problem for the G.T.M. —how could an endless belt be installed here?



Simple, when you know how

How this is done—how cords can be dovetailed together—is shown by the diagrams pictured here. And the result—installed on the drive—is still an *endless* belt, with all the advantages which make the Goodyear COMPASS Cord belt *the first major improvement in belt design in fifty years.*